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PROGRESS REPORT ON
RESEARCH AND DEVELOPMENT
IN THE FIELD OF
HIGH ALTITUDE PLASTIC BALLOONS

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PROGRESS REPORT ON CONTRACT # 710 (01)

From June 15, 1952, to December 22, 1952

VOLUME VI

SECRET SECURITY INFORMATION

Table of Contents

Section I - Project Summary and Prognosis	Pages I-1 - I-14
II - Flight Summaries	Pages II-15 - II-104
III - Operations Charts	Pages III-105 - III-106
IV - Ammonia Summary	Pages IV-107 - IV-118
V - Ballasting Systems	Pages V-119 - V-126
VI - Sunset Effects	Pages VI-127 - VI-136
VII - Balloon Meeting	Pages VII-137 - VII-144

SECTION I

PROJECT SUMMARY AND PROGNOSIS

The organization of the Balloon Project during the period covered by this Project Report, June 15 to December 22, 1952, is much the same as the organization at the end of the period covered by the first Project Report. There are now a total of 47 people working on the project and the project has stabilized at this level of activity. During the period covered by this report, 35 balloon flights have been made. Because he was urgently needed at Los Alamos, C.L. Critchfield, who is the project director, has only been able to spend half of his time at Minnesota, spending the other half at Los Alamos. Ney and Winckler in his absence have handled the administrative details of the Balloon Project.

Most of the balloon flights which were made in this project were made with Winzen balloons, either furnished by Winzen's support contract or bought directly by the University of Minnesota with project funds. At the time of writing this report, Winzen and General Mills, Inc. are negotiating for separate support contracts to supply us with balloons to our specifications for the duration of the project. In addition to this, a new contractor, Herb Shelly, Co. of Farmington, Minnesota, has been interested in balloon manufacture and has supplied us with a number of Mylar cylinder balloons. Certain quality control techniques are being tried out with this contractor and the possibility of using Mylar in stratosphere balloons of the cylinder design which is described in detail in this report appears to be very promising. The advantage of the Mylar balloons is that they can be economically made without the use of tapes because their strength is extremely high, approximately 5 to 10 times higher per unit weight than polyethylene.

The Launching Section of this report contains a summary of our experiences with the University of Minnesota launching method in a series of 55 launchings on the Balloon Project. The general experience has been that the launching method is completely adequate for our project as it allows us to launch under rather adverse wind circumstances and at the same time weigh the balloon off. In the entire series of launchings represented in the University of Minnesota Project there has not been a single case of a balloon not having adequate gas in it. Several minor modifications in the details of the packing and launching method have been made and these are described in the launching section of the report. A cost analysis of the packing cost indicated that it adds approximately \$400 to the cost of the balloon which in the case of the University of Minnesota Project is a reasonable price to pay for the possibility of being able to launch on schedule rather than having to wait for weather. A series of 15 flights were launched in Texas by this method and all were extremely successful.

The section of the report concerned with Balloon Design begins with some considerations on balloon shape. The idea of the natural shape balloon which was first put to practical use by General Mills, Inc. in the later stages of the GOPHER Project has been carried considerably further in experiments made by the University of Minnesota balloon group. In particular, calculations on the REAC computer made it possible to determine the exact natural shape for a multitude of conditions. These calculations could not have been carried out by hand and the REAC calculator solutions have been a very valuable contribution to the art of balloon design. The so-called natural shape balloon is that balloon which has zero circumferential stress and which carries the load and gas pressure by converting the tension to so-called meridional stress or stress along the plastic in the vertical direction, (i.e. along the gore). A balloon which has enough material in it to take on the natural shape therefore has essentially zero tension working around the circumference and therefore shows

no tendency to open up at heat seals where the material is fastened together. The function that the tapes had played in the past, strengthening this point of the balloon which is probably the weakest point, is therefore no longer necessary. Previous experiments had shown that tapes, except for their load carrying ability, are detrimental to balloon performance. Design considerations now stress elimination of tapes. Elimination of tapes, of course, is important also from the standpoint of super-heat and when the tapes are eliminated the magnitude of sunset effect is greatly diminished. As an example of the use of the REAC computer in balloon design, the data are included on REAC calculated shapes for the MOBY DICK natural shape balloon. In this case the calculations were made including the weight of the balloon which was furnished to us by the MOBY DICK Project and the shape that was calculated then represents the natural shape balloon for this particular situation. Also included in this section is a complete series of calculations on natural shape balloons which showed the way in which the volume of a natural shape balloon, in particular a cylinder balloon, is dependent upon the position of the zero pressure level in the balloon. The position of the zero pressure level can in turn be determined by the use of the duct appendix which has been developed in the course of the work on this project. The calculations which have been made relate the various quantities of balloon design, the meridional tension, the cone angle, height, diameter and volume to the position of the zero pressure level in the balloon. A series of hangar tests were made in which the lift of a polyethylene cylinder balloon was measured as a function of the position of the zero pressure level in the balloon as determined by the duct and these experimental points are included to show the striking agreement between theory and experiment. It is possible by use of this theory to take a given set of dimensions for a cylinder balloon and determine the theoretical volume which this balloon will have when it is operated at any condition of super- or sub-

pressure. The section also includes a complete discussion of the use of cylinder balloons as natural shape balloons and this discussion is based on the fact that if one makes a natural shape balloon without the use of tapes, the geometrical configuration which one starts with in order to distribute the meridional stress uniformly throughout the balloon turned out to be a cylinder. This is indeed fortunate from the manufacturing standpoint since the cylinder balloons can be made by simply heat sealing straight gores together and the balloon which is produced in this way is simply a balloon cylinder. The cylinder can then be secured at the two ends and the tension is therefore transferred directly from the balloon plastic to the load. The most spectacular demonstration of the success of the cylinder balloon idea was demonstrated in hangar inflation of a six pound Mylar cylinder balloon which lifted 600 pounds when it was inflated in the hangar. This was a 25' diameter 45' long cylinder and the weight which is lifted (100 times its own weight) was not producing ultimate tension in the material. The test was stopped at this stage because of the fact that the dimensions of the cylinder were such that circumferential tension began to appear when the balloon had acquired this lift.

This section also contains a description of the various attempts of this project and others to design an effective appendix capable of excluding air from the balloon system in all phases of its flight. The culmination of this appendix design study came with the invention of the duct appendix which allows a balloon to ascend or descend without intaking air under any conditions and therefore makes it a vehicle capable of vertical control over an extended period of time. In previous balloon designs and experiments the appendices which were essentially open to the outside air allowed the balloon on descent to take in large quantities of air and therefore would prohibit it from reaching its initial ceiling once it had descended. At

the low pressures normally encountered in stratosphere flights the air which is intaken in a balloon has sufficient time to mix with the helium and therefore produces a contaminated mixture which lowers the theoretical ceiling of the balloon. Essentially all of our flights from flight #40 on have been made with this duct appendix and have demonstrated conclusively that the duct appendix is completely effective in excluding air from the balloon system both on descent and ascent. Once the air was excluded from the balloon, the study of the characteristics of the balloon has proceeded much more rapidly, since the effect of an unknown intaken quantity of air had made the interpretation of previous balloon flights extremely difficult, if not impossible.

During the time that this Project Report covers we were asked by the Steering Committee to consider the RDB problem of a super pressure balloon. A study was made on this super-pressure balloon based on more or less conventional balloon design to determine whether or not it would be possible to design a plastic balloon capable of enough super-pressure to go through sunset without losing this super-pressure. It was found that a balloon of conventional design could not hold the required super-pressure without bursting and therefore the idea of a conventional super-pressure polyethylene balloon of large size, greater than 30' or 40' seemed to be unfeasible.

The studies on Mylar cylinder super-pressure balloons, however, indicate that it may be quite feasible to operate balloons with sufficient super-pressure to allow them to go through sunset provided that this super pressure does not increase the leakage to an impossibly high value. Future experimental work on the Project will investigate this possibility of Mylar super-pressure balloons capable of surviving the sunset effect.

During the period June 15 to December 22, 1952, a series of tests were conducted in Weeksville, North Carolina, on conventional cone-on-sphere and taped natural shaped balloons of the type used in the later stages of the

GOPHER work. These tests in the Navy hangar consisted of studies of completely inflated SKYHOOK cells lifting from several hundred to 2000 pounds. The balloons which were used in the test consisted of all of the types of balloons which we have been flying on the balloon project, both double and single wall balloons of Winzen manufacture, 1 and 2-mil balloons that General Mills manufactured of the cone-on-sphere design and a natural shape 2-mil double taped balloon of General Mills manufacture. Shape and tension measurements were made on all these balloons and a complete photographic study of this series of tests was taken. In addition to the inflation test described, a balloon was launched by the Minnesota launching method inside the hangar to investigate various features of this launching method such as the slipping of the girdle while the balloon is filling out during its period of vertical flight. Because of the fact that helium and air mix very slowly at atmospheric pressure it was necessary in these tests to design and build a carburetor which was capable of adequately mixing the air and helium on inflation of the balloon. Enough helium was put in the mixture to produce the desired quantity of free lift. The method was quite successful and a series of pictures are included in the appropriate section of this report showing the appearance of these fully inflated cells. In order to demonstrate the slow mixing of air and helium at sea level atmospheric pressure and to measure the super-pressure required to burst a conventional cone-on-sphere balloon, the balloon which was used to study the University of Minnesota launching method in the hangar was blown full of air after this test was completed. It was found that only a small quantity of air could be put in the balloon normally because of the fact that the air and helium do not mix and if the blower was turned off the air which had been blown into the balloon would just blow back out of the appendix in spite of the fact that the balloon was very far from being fully inflated. In order then to carry out the super-pressure bursting tests it was necessary to continue to blow the air in the balloon until the point of bursting was reached. It was found that the bursting failure occurred exactly at the

the point where the stresses theoretically had been shown to be highest, namely at the point where the cone joins the sphere and on bursting, this 1-mil balloon showed a meridional tear right at the position where the cone joins the sphere. Several unsuspected properties of these fully inflated cells were discovered in the Weeksville tests and the investigators felt that these tests had been so illuminating that no new balloon design should be flown without first being tested in the hangar in the manner in which these balloons were tested at Weeksville.

Prior to the invention of the duct appendix it was realized that the mixing of gas in balloons (air and helium for example) was an extremely important question in balloon theory. Therefore, a series of calculations were made on the rate at which gas mixing can occur in a balloon at different pressures. These calculations give quantitative answers to the question of what length of time is required to mix air and helium in a balloon at different pressures, and to the question of how much air is taken into a balloon and mixed by the mechanism of diffusion through the skirt appendix which was previously used at the bottom of SKYHOOK balloons. The calculations show that the mixing time is directly proportional to the pressure at which the balloon finds itself. Therefore, the mixing time is quite long at atmospheric pressure, perhaps hundreds of hours whereas the mixing time at 10 mb may be as short as an hour or less. This means, of course, that air that is intaken on the ground could be valved out at high pressure but air which is intaken in a balloon near ceiling very frequently can have time to mix and therefore greatly distort the behavior of the balloon system. It is also shown that balloons floating at high altitude would lose several per cent a day of lift due to the diffusion of air into the balloon through the open skirt appendix. This effect is also extremely undesirable and the quantitative realization of the effect of diffusion made the development of an effective appendix a necessity.

The section of the report on vertical flight contains a summary of our knowledge at the present time of the factors involved in vertical (either upward or downward) motion of a balloon. This section is in a sense a summary and should be read in detail. It may be briefly summarized here, however, in the following way. The quantities which determine the behavior of a balloon in any circumstances either rising or falling, are the free lift which the balloon has and the net drag. Although the problem sounds simple in principle the free lift of the balloon on the ground at take off will be quite different from the free lift the balloon has as it rises to the stratosphere through the atmosphere. The reason for this is that weighing a balloon off on the ground simply guarantees a free lift under the temperature circumstances which exist on the ground. However, since the atmosphere cools throughout the troposphere the free lift which the balloon would have at rest at any position other than the ground is determined by how much warmer the balloon fabric would be than the surrounding air. At the present time the estimate of the magnitude of this effect is that a balloon which is exactly weighed off on the ground would have something like 5% free lift at the base of the stratosphere for a 1-mil taped polyethylene balloon. This means, of course, that the time altitude curve is greatly affected by this acquisition of super-heat for a balloon at different altitudes. To complicate matters further it is not possible to equate this free lift (presumed known) to the aerodynamic drag in order to determine the rate of rise of the balloon. The reason for this is that the balloon is a rather complicated thermodynamic system once it is set into motion. In order to have a balloon rise through the atmosphere it is necessary for heat to flow into the system and in particular as soon as the balloon begins to rise the adiabatic expansion of its inside gas would cool tending to neutralize the free lift were it not for the fact that heat can flow through the plastic and the balloon can then rise with a definite temperature difference existing between the inside gas and the out-

side air. Since this effect is due to the motion of the balloon, it has been termed thermodynamic drag and is one of the most important determining factors at slow rates of rise and at high altitudes in discussing balloon performance. After the introduction of the duct appendix, very illuminating thermodynamic effects have been observed in balloons whose state of motion is suddenly altered by the dropping of a discreet quantity of ballast. These thermodynamic effects allow one to measure the change in temperature of the balloon gas by using the balloon itself as a thermometer and observing the altitude change accompanying a change in state of the balloon's motion produced by the dropping of ballast. These marked thermodynamic effects have not been observed in the past because they would be almost completely obscured, provided that the balloon were allowed to take in air, thereby eliminating the possibility of rapidly changing its altitude. The various factors involved in vertical flight are now well appreciated and future work in the project in this connection will consist of more accurate determination of the magnitudes of the temperature field in which the balloon finds itself, the thermodynamic and aerodynamic drag at various altitudes and at various rates of rise since these quantities are important in determining the control characteristics of any system which would control the vertical flight of the balloon.

The instrumentation and telemetering sections of this report describe the developments in those fields which we considered necessary in order to study the balloon system. Block diagrams and photographs of various exhibits are used to describe these developments. The pressure measurements are made by means of an improved Olland Cycle primarily because of the high relative accuracy of such a system. Gear is described which has been used for the radio control of the vertical flight of the balloon by means of ballast dropping and valving. The characteristics of the radio control receivers, transmitters and antennas and so forth are described in some detail. In

addition to our fixed station at the University Airport at Minneapolis we have a mobile semi-trailer which is equipped as a laboratory communications center which during the winter months is maintained at Pierre, South Dakota. This mobile tracking unit has been a very valuable addition to our balloon operations.

For detailed information about the flights that have been made on the Project the flight summaries and the operations charts are an important part of this report. The flights are described in detail including the objectives, the actual operation and the results in each of these balloon flights. The operations charts summarize some of this information in chart form to make it easy to see at a glance the behavior and purpose and details of launching, recovery, weather, etc. about the individual flights. This procedure of writing a flight summary and making operation charts was introduced in the first volumes of the Minnesota report.

A section of this report is concerned with summarizing the flights which have been made by our group using either pure ammonia or diluted ammonia mixtures as a filling gas. For many military applications because of the logistics of the situation, ammonia as a filling gas may be either desirable or necessary. It was therefore felt that some experience should be acquired on flying balloons with ammonia as a lifting gas and a number of successful flights have been carried out with pure ammonia and with mixtures. Ammonia behaves quite differently from helium as a lifting gas for several reasons. First, its relative weight is so high that the balloon itself has a large inertia since it has inside of it a very large weight of lifting gas compared to the same balloon with helium. On launching ammonia balloons these inertia effects are very manifest. Because of its very high infra-red absorption, ammonia balloons become sensitive to changes in infra-red flux and it was initially hoped that the fact that the infra-red flux increases as one approaches the earth would allow ammonia filled balloons to become stable after

descending a certain distance. This has not been demonstrated conclusively although in a number of instances the change in infra-red flux in the atmosphere produced a very definite stabilizing effect on the balloons. Unfortunately when the ammonia flights were made the duct appendix was not available so the effects of intaken air are not clearly delineated. In the next series of flights, ammonia flights will be made and the effect of ammonia absorption will be directly measured as well as the flux of infra-red radiation coming from the earth. No particular difficulties were encountered in flying ammonia balloons from an operational standpoint although some precautions were taken, such as the wearing of gas masks by the personnel in the vicinity of the balloon. A system of evaporating ammonia into the balloon with the heat exchanger and a steam jenny needed to be designed for these flights since ammonia has such a high heat of vaporization that it must actually be boiled into the balloon by supplying heat to the evaporating system. The possibility of ammonia condensation and subsequent balloon instability has been noted in troposphere balloons by flights conducted by the Air Force Cambridge Research Directorate. This has not been observed in the Minnesota project where only stratosphere flights were conducted with ammonia.

A survey of the efficiency of ballasting systems has been carried out. The ballasting systems considered are containers filled with compressed gas, liquid hydrogen, liquid helium, ammonia and a hydrogen generator based on the use of Lithium hydride. This study was initiated in the belief that if the sunset effect could not be appreciably reduced in balloons, the conventional ballasting system of dropping shot might need to be replaced by a more efficient but more complicated system. The relative merits and difficulties associated with all these ballasting systems are enumerated in detail in this section of the report. Operationally, none of the systems have been tested and in our flights the ballasting has been carried out almost entirely by the use of

steel shot as was done in the MOBY DICK Project. The possibility of reducing the sunset effect shown by Mylar balloons may mean that complicated ballasting systems will not have to be used in any application. It is hoped that the answer to this question will be available before the termination of this project.

It has been demonstrated that with balloons operated in more or less conventional ways that the sunset effect is the predominant cause of loss of lift. Balloons can be successfully built and launched in such a way that leakage constitutes a very much smaller loss of lift than the sunset effect which may amount to from 6 to 10% of the air displaced in flights made with polyethylene balloons. For military applications one may tend to pay for the sunset effect by carrying large quantities of ballast to prolong the flight and in doing so create a need for making a heavier balloon which in turn will have a larger sunset effect and will call for even greater ballast loads. It can be seen that one will soon reach a region of diminishing returns using this approach. The balloon project has been concerned with making measurements of the magnitude of the sunset loss of lift and the velocity which is acquired by a balloon which is allowed to freely descend at sunset without ballast drop. The purpose of these measurements and this study has been to search for a means of reducing the sunset effect to a magnitude which can reasonably be paid for by ballast drops for an extended length of time. Experiments with 1-mil polyethylene balloons have shown that leakage rates on the order of less than a per cent per day can fairly readily be obtained. This would mean, of course, that a time constant of the system for leakage would be of the order of 100 days. In other words if the leakage were paid for by dropping ballast the weight of the system would drop to $1/3$ in a time on the order of 100 days. On the other hand the sunset effect on these balloons may be as high as 10% giving a time constant of only 10 days. Since military applications would not be satisfactory with a take off weight

three times as heavy as the delivery weight the time constant specified by the sunset effect of 10 days, is perhaps not actually realizable in practice. It has been demonstrated that much thinner balloons can be constructed of Mylar with a consequent reduction in magnitude of the sunset effect by a factor of two to a factor of three. The consequent increase in the time constant for flight makes it almost feasible with a $\frac{1}{4}$ -mil Mylar balloon to pay for the sunset effect each night and maintain level flight at the prescribed ceiling. It is, however, not demonstrated at this time that Mylar will be able to stand extended exposure to the ozone and ultra-violet of the stratosphere. An analysis of the flight data leads to a very simple relationship between the rate of descent of the balloon at sunset, the total weight of the balloon and the weight of air displaced. This analysis shows that the sunset effect will be minimized by making the ratio of the weight of the balloon to the weight of displaced air a minimum. The analysis also shows that conventional balloon materials and also Mylar seem to absorb solar energy at the rate of about 20 watts per pound of material. An alternative means of reducing the sunset effect would be to find some way of reducing this absorption of the solar energy below the barrier of 20 watts per pound. At the present time it appears no plastic is available which will better this figure and therefore other methods compensating for the sunset effect must be used. In the next period of this project considerable effort will be concentrated on the problem of minimizing the ballast cost of the sunset effect.

This report also includes time-altitude charts, temperature soundings and meteorological trajectories for all of the flights of the series for which this data could be obtained. The data are presented in much the same form as they were in the first report.

The analysis of the wind data obtained from the plastic balloon flights is presented in this section of the report. This section actually consists of two separate reports: one concerned with the analysis of the wind measurements while the balloon maintains level flight; and a second report which reviews several studies of some aspects of the winds observed during the ascent of the balloon. The report on the winds at altitude entitled "Characteristics of Stratospheric Flow" is believed to provide a representative survey of the flow characteristics for the latitude and season investigated. The group of studies covered by the second report have not been carried to the same stage of completion, and this portion of the report merely represents an attempt to collect some rather diverse fragments of information on the atmospheric region just above the limits of conventional meteorological analysis.

SECTION II

FLIGHT #21

This flight was launched June 25, 1952, at 1100. It was a General Mills 1161 balloon to which we attached an appendix with slats. This balloon is General Mills' version of the natural shape balloon for the case of negligible balloon weight. It was made of 1 mil thick polyethylene, DE-2500, with #880 tapes, 42 gores, 116 feet diameter, volume of 715,000 cubic feet and balloon weight of 261 pounds. The balloon was packaged in Williams Arena, but due to the greater length, the upper two thirds could not be hung clear of the floor for inserting the tire and valve. Accordingly, the balloon was suspended upside-down from the load ring, and the tire was inserted one third of the way from the bottom of the balloon. The tire and valve had to be equipped with a second suspension ring on the diaphragm side of the tire in order to handle it. After the girdle was installed and the balloon clamped, it was lowered to the floor, then hung from the top and the packaging completed in the usual manner. There was no difficulty at any time in carrying out the packaging by this method, and it suggests that the same procedure could be followed on the smaller balloons in a building with less head room than the 95 feet available in Williams Arena. When the balloon is packaged in this manner, the diaphragm ripcord tends to roll around on the diaphragm, and there is evidence on this flight that this ripcord may have become clamped in under the girdle accidentally. This difficulty can certainly be eliminated, but is not present at all when the balloon is wrapped right-side up for installing the girdle. The day before the flight a rather severe windstorm had taken about half the boards off the windscreen, making it essentially useless for a wind shield. Because of this we launched out in the open in a 4 knot wind. The sky was almost completely overcast. Mantis had informed us

that the day of this flight there was a definite jet stream. St. Cloud lost their balloon at 25,000 feet in a 100 knot wind. The winds at lower elevation were quite light, indicating a large shear in the atmosphere. The inflation medium was ammonia. The purpose of the flight was to determine the characteristics of the time altitude curve during ascent with ammonia and to investigate the duration of a non-ballasted ammonia filled balloon. The flight was equipped with standard instrumentation, including a blow down box which puts a warbling note on the telemetering one minute prior to timer release. The inflation proceeded very smoothly with the exception that the carburator on the jenny had to be adjusted. After the jenny was in satisfactory operation the inflation took place in 37 minutes. The amount of displaced air was 1170 pounds and the gross lift was 483 pounds. The weigh off took place only in the horizontal position and was carried out simultaneously on both ends. As soon as the top of the balloon was let up on the rope, the launching took place directly to keep the balloon from being subject to damage in the wind. After take off, the balloon disappeared in the overcast in about four minutes. At this stage, it was evident that the heavy canopy of the balloon had fallen over the side and later observation of the ur pictures showed that this definitely obstructed the flow of gas. The balloon, however, did inflate its top in approximately 53 minutes, but the girdle never did come down the balloon. The tire is not in evidence in any of the pictures. After the top had inflated, the balloon continued to rise and after two hours and 17 minutes of flight it broke at 47,600 feet in a jet stream. Magnus was able to follow the signal on the load until impact, and discovered the load on the ground in this way. Only 8 minutes were required to fall from 47,000 feet and the equipment was rather badly damaged. However, all flight records, including movie film, were good. Although it was determined that the aerial blowdown fired

properly on the way down at 30,000 feet, the remnants of the balloon trailing above the gondola did not pull the parachute ripcord and open the chute.

Conclusions

The 3/4 million cubic feet balloon very probably requires a larger girdle for a proper inflation of the top with ammonia. The flight showed the increasing rate of rise characteristic of ammonia flights and added some weight to our feeling that 1 mil balloons, at least, have difficulty surviving high jet stream winds. There is evidently a weakness in the use of a packed chute in case of balloon failure. Some special precaution obviously is necessary to insure that the parachute ripcord is pulled as only small fragments of the balloon are left attached to the gondola at the time of failure.

FLIGHT #22

This flight was launched June 30, 1952, at 1515. It was a Winzen 1.5 mil thick, 72.8 foot diameter balloon equipped with destruction tape, short appendix, 11 meter antenna, polished aluminum girdle and manufactured with glass filament tapes. This balloon was initially packed May 7, and on June 9 was rehung in order to repair the antenna. It weighed a hundred and seventy seven pounds and for the purposes of the flight, which were to obtain flight constants and operate and test a command ballast and blow down system, the balloon was equipped with a 1 inch diameter hole near the crown so that ballasting would be necessary during the daytime as well as at sunset. The planned duration was 22 hours and the theoretical ceiling 83,000 feet. The gondola contained ballast tank #2 filled with 100 pounds of fine steel shot. A magnetic ballast valve, #1, made according to designs of the Howell group at Tufts College (Moby Dick), was used to replace the worm drive type used previously. Ballast level transmitter #3 and ballast level recorder #2, the latter making a smoked disc record on the barograph drive, gave readings of the total ballast head remaining. The transmitter was on 1746 kc with Olland cycle #7 for pressure modulator. The same modulator was also fed into a 132 mc transmitter frequency modulated Maas command receiver #7 operated on 6420 kc and by means of two resonant release and two time delay relays operated either the ballast release or the blow down squibs. Additional equipment consisted of a blow down box with low altitude blow off and warble modulator one minute before release, up and down cameras, blinker beacon #6, baro-thermograph #8 and timers. Two packages of nuclear emulsions were also carried. The inflation medium was helium and the final inflation just before launching was made to a free lift of 61 pounds with a gross load of 478 and 631 pounds of displaced air. The weather was clear with a 10-mile per hour steady ground wind. In-

flation was begun with the balloon in the horizontal position as usual. After most of the gas was fed into the balloon it was noticed that the inner bubble was collapsing and the helium was transferring into the space between the inner bubble and the canopy. It was presumed that there was a leak in the inner bubble near the bottom of the balloon. Attempts were made to salvage the flight by cutting slits through the balloon near the top to permit gas to escape from under the canopy and by walking the balloon to an upright position so that these holes would be in a favorable place for escaping gas. Little gas escaped, however, so the balloon was pulled back down to the ground. At about this time, the large amount of lift under the canopy pulled it out from under the corset and it liberated the gas and fell loosely around the partially inflated inner bubble. The inflation plug was then removed and the lower end of the balloon allowed to raise, and the rest of the gas escaped. It was found on examination that the bottom of the balloon, just above the point where the inflation plug is clamped by the corset, was badly ripped and shattered all the way around. Evidently the blast of the inflating helium had been strong enough to tear the balloon severely. The balloon was completely repaired on the spot with polyethylene tape and the inflation thimble was clamped back into the bottom of the balloon. The canopy hung from the girdle and lay on the ground under the balloon. The balloon was re-inflated, weighed off, and launched without undue difficulty, with the entire canopy hanging over one side of the balloon. The balloon rose at about 1,000 feet per minute, but no gas transferred into the canopy. Apparently its weight was enough to close off the valve opening at the top of the inflated bubble. At about 5,000 feet altitude the girdle and tire separated, the girdle was quickly skinned off the top of the balloon, and the balloon extended itself to full

length. It was soon evident that the balloon was settling and it landed about two miles north of the airport in a vacant pasture. The sliding girdle evidently tore a large hole in the upper portion of the balloon. The girdle itself was found across the street on a farm. The gondola was severely damaged by the impact, but both balloon and gondola were recovered without difficulty. Signals were received during the 10 minute flight from the 132 mc transmitter and the 1746 transmitter. The antenna of the latter dropped just as the girdle loosened at 5,000 feet. Signals were still being received with the transmitter on the ground. The antenna was stretched out on the ground full length in a perfectly straight line below the gondola.

Conclusions

This launching attempt served to point out several weak places in the launching technique. It is clear that the balloon must be protected from the cold blast of helium coming through the inflation thimble by a suitable diffuser. A possible major source of difficulty is indicated if the canopy slips off the inflated bubble before an appreciable amount of gas has transferred. The weight of the canopy then prevents the flow of gas and this blocking off is increased by the aerodynamic pressure on the top of the rising balloon. This behavior was also shown on flight #21. It seems that a certain minimum amount of gas must be transferred positively before there is any chance of the canopy slipping all the way to one side in order to insure the successful extension of the balloon in the air.

FLIGHT #23

The preparations for flight #23 were made on July 3, 1952. The balloon was a General Mills 1161, #A-3273, #19, equipped with glass filament tapes, a short appendix, and a taped aluminum girdle; also an 11-meter vertical antenna. The balloon weighed 247 pounds, and the theoretical ceiling was 106,500 feet. The purpose of this flight was to measure the flight characteristics and sunset effects on a 116 foot diameter balloon, and the planned duration was 22 hours. Gondola #6 was equipped with both 1746 kc and 133 mc transmitters, and a 6420 kc command receiver; also low altitude blow down, up, down and horizon cameras, and 60 pounds of steel shot in four 15 pound bags arranged to be dropped by command when needed. A package of 4 x 8 plates from George Anderson, plates from Shapiro, and a special set of plates with a chute, to be dropped by a timer, were included. Blinker beacons, baro-thermographs, and the usual flight equipment were also included. The total gross load was 504 pounds. This balloon was packed in Williams Arena, but because of its large size, the girdle and diaphragm tube were inserted with the balloon hanging upside down. The balloon was then lowered to the floor, and the canopy folded over in the usual way, without any difficulties. The balloon was laid out in a rather high wind of 20-40 miles per hour with gusts off the eastern end of the windscreen, which had, at this time, been damaged by a previous storm. Inflation proceeded for a time without difficulty, but when enough helium had been admitted to the balloon to lift the fabric off the ground, the gusts filled out the large amount of loose fabric like a sail, and created enough force to snap the 1000 pound tie down line at the top of the balloon. The balloon then erected violently and broke the pulley at the bottom tie down point. The balloon was then held by the block and tackle to one of the guy ropes of the windscreen, and soon was destroyed by beating around against the windscreen. The operation was

then concluded.

Conclusions

Much stronger handling rigging should be used, so that gusts can be handled against the balloon fabric. It is probably that the diaphragm tube and girdle would support such strain if a sufficiently strong tie rope were used. Subsequently, balloons were rigged with 3000 pound test nylon and cold-rolled steel pulleys.

FLIGHT #24

This flight was launched on July 8, 1952, at 1333. It was a double-wall Air Force balloon manufactured by Winzen, had glass filament tapes, nylon taped girdle, 6-foot standard appendix, and was equipped with an 11-meter antenna. It was packed on June 20 by Smith, Lahti and Edwards.

The purpose of the flight was to test the infra red ammonia balloon behavior by using a dilute ammonia-helium mixture which would cause the balloon to become opaque to earth radiation at the size the balloon takes on at 50,000 feet. This means that at 50,000 feet the number of gr/cm² of ammonia in the balloon corresponds to 1 absorption length. The value of the absorption length was found from the literature to be 5 mg per square centimeter. This means, of course, that at lower altitudes than 50,000 feet, the balloon is essentially completely opaque, and at altitudes above 50,000 feet (neglecting absorption in the atmosphere above this altitude) the balloon absorbs a constant amount of energy.

A further purpose of this flight was to continue experiments with double-wall balloons to try and discover whether or not the effect of descent after reaching altitude (Howell effect) was a property of these balloons.

Also included on this flight was a command ballast drop and a command blow down of the equipment in case of early failure. As the experiment turned out, it was not possible to attempt the ballast drop because of the way the experiment was going until very late in the flight, and it was not found possible to carry out this part of the experiment. The planned duration of the flight was 22 hours, and the actual duration was 21 hours, 31 minutes.

The flight carried a standard gondola equipped with a 1746 kc transmitter, as well as the rest of the standard instrumentation. This included a blow down box, up and down cameras, and an additional camera arranged to photograph the horizon. The total amount of ballast which could have been dropped consisted of 30 pounds. This flight also carried monitoring cosmic ray plates which will be mounted from this flight forward as a standard part of the instrumentation.

Because of the previous damage to the windscreen, the launching took place some distance away in a 5-knot wind. The cloud cover was 5/10 cumulus and a jet stream of 110 miles per hour had been reported by St. Cloud. It was found during the flight that no jet stream existed at our position since no high westerly winds were observed.

The inflation consisted of a mixture of helium and ammonia, the mixing taking place in a pipe consisting of coaxial cylinders with the ammonia injected in the center cylinder at approximately 100 pounds per square inch pressure. The inner cylinder was equipped with 19 small holes which allowed the ammonia to jet out into the passing stream of helium. To give an idea of the actual amounts of helium and ammonia, approximately 70 pounds of helium and 30 pounds of ammonia were used. The air displaced was 576 pounds, gross lift 494, gross load 434, giving a free lift of 60 pounds. This is 10.4% of the air displaced. The initial rate of rise was 860 feet per minute, which increased to 1,000 feet a minute between 300 and 100 mb and to 1270 feet per minute as it approached ceiling.

Operationally the flight went very well. The launching went smoothly, the girdle dropped at 1405 and the flight approached ceiling with a square corner on the time-altitude curve, characteristic of an appendix which keeps air from sucking into the balloon. Telemetering was carried out satisfactorily throughout the day and part of the night, and tape recording of the telemetered record was made in a portable unit, so we have essentially

complete coverage of the flight except for a period during the middle of the night. This period is filled in together with a duplicate of the rest of the record by the barograph record. The balloon floated at 83,000 to 84,000 feet, absolutely level during the day. When the sun set on the balloon, it started down and leveled again at an altitude of about 72,000 feet. This altitude was maintained throughout the night. When the sun rose, the balloon climbed from 71,000 to approximately 75,000 feet and floated level during the next day until it was released by the timers. We believe that the reason the balloon only climbed 4 to 5,000 feet when sunrise occurred was that during the night, air had been taken in and mixed with the helium and that at sunrise this mixture was valved. All of the indications on this flight are that if an effective appendix had kept air out during the initial descent after sunset, the balloon would have climbed back to its original ceiling on the second day.

A rough calculation was made to determine the effect of mixing of air and helium in a balloon. This calculation indicated that at pressures of the order of 2cm the mixing of the air and helium can take place in a time of the order of hours, whereas, the mixing time required at a pressure of 200 cm would be about 100 times longer. This probably explains why a balloon which descends rapidly at night to a very low altitude is able to climb back the next day when the sun rises. This would be because the air which is taken in during the descent is not mixed with the helium, and the balloon can valve out essentially pure air which, because of its super heat, would give the free lift necessary to create a rise the next day.

In our flight the leveling off occurred at a relatively low pressure - approximately 40 mb, and during the night the air which was taken in at the beginning of the night very probably mixed completely with the helium,

and the valving which took place was then of a completely mixed helium-air mixture.

We believe that the very remarkable behavior of this balloon is probably due to the needling of the balloon with ammonia which would make it opaque to earth radiation and would thereby cause it to acquire super heat as the balloon descended at night and allow it to become stable at some new altitude. The flight was recovered the next day. All equipment was found, including the balloon. The load was recovered at Sioux Falls, South Dakota, and the balloon was found 3 miles from the load. An airplane was sent out to home on the parachute during descent but did not arrive on the scene in time. It was reported by the observers underneath the balloon that the radio signal was received until the time of impact of the load on the ground. This is further evidence that the lead ball on the end of the antenna dropper is adequate to keep the antenna out after the load is released.

Conclusions

The Air Force double-wall balloons are very probably all right since this flight showed that these balloons can be made to level off very properly. The overall behavior of the flight indicated that the leakage of these balloons can be very low. The technique of needling the helium with ammonia appears to offer great promise for long duration flights, indicated by the leveling off of this balloon during the night. It is indicated from this flight that in order to achieve optimum performance in terms of having the balloon rise to the highest possible ceiling on the second and successive days, it is necessary to have an appendix which does not allow the intake of air at times when the balloon is descending. The preliminary indications

from this flight are that the previously reported effect that a balloon, once it has dropped from its original ceiling, cannot be made to easily return to that ceiling are probably the result of intake of air, mixing this air with the helium, and then valving the mixture rather than valving of pure air.

FLIGHT #25

Flight #25 was launched on July 15, 1952, at 1045, at the University Airport, north-northeast of the windscreen in a 2-5 knot wind. The cloud cover was approximately one-tenth cumulus. The balloon was a Winzen 73 foot by $1\frac{1}{2}$ mil with #890 tapes, an 8-foot standard appendix, and an 11-meter antenna. The balloon weight was 180 pounds, and the theoretical altitude was 80,500 feet. The purpose of the flight was to test a command ballast system, a command blow down system, and to obtain flight constants for a balloon nearly full and floating near its ceiling altitude. In order to create a loss of lift during the flight, a $\frac{3}{8}$ inch hole was left in the top of the balloon to allow leakage which would have to be compensated for by dropping ballast. Because we have been having some trouble with getting the corset off properly, and having the corset open to the new position rapidly enough, we installed a foam rubber insulator between the corset and the balloon. It was hoped that this foam rubber would also keep the tight corset from damaging the balloon. The instrumentation included the ballast hopper, the 1746 kc transmitter, an up-camera, a down-camera, a crown camera, 100 pounds of steel shot ballast, and a radio operated magnetic ballast valve. The inflation was pure helium, and 570 pounds of air were displaced. The free lift was 48 pounds.

During launching, a foul-up in the diaphragm ripcord, together with the fact that a new man was pulling this ripcord, created a situation in which the balloon took off without the diaphragm having been ripped. The balloon rose normally to about 9,000 feet, with the canopy hanging normally and not falling off to the side. Because of the fact that the diaphragm had not been ripped, gas was valved at about 7,000 or 8,000 feet, and this gas flowed up underneath the canopy, and held it out rather like a mushroom. At this

stage, it was realized, of course, that nothing would happen unless it was possible to drive the balloon up to the altitude at which the tire deflator would deflate the tire and allow the canopy to erect. This was attempted by radio-controlled ballast dropping. Command was established on the ballast dropping radio link and approximately 5-10 pounds of ballast were dropped before command was lost. We attempted every possible means of regaining control of the ballast drop, but were unsuccessful. It turned out, after recovery of the equipment, that a resonant relay, used to control the ballast drop, had failed in flight. When it was discovered that we could no longer drop ballast, and therefore had little chance of changing the situation, we decided to blow down the balloon by radio control. Because it was in the air lane at about 10,000 feet, it would definitely present a serious hazard to air navigation, and the timers were set for 24 hours. Command was immediately established by the radio channel and the radio blow down operated perfectly satisfactorily. The load released from the balloon. As soon as the load fell away, the balloon turned over, spilled its gas, and both balloon and load were recovered near to each other at a position about 1.25 miles west of Hugo, Minnesota. The gondola was in very good shape, although these heavier loads, falling on a single parachute, tend to be damaged considerably more than the loads that we flew on earlier flights.

Conclusions

We again completed the radio control link. This is further indication that radio command operations can be adequately carried out. This flight did teach us that it was necessary to have individual tests on resonant relays delivered to us, to determine what the minimum operating power of the relay was, and to be sure that the relay was not going to fail early in its life. It is clear from this flight that the personnel

who operate the ripcords must be made to practice this operation beforehand, and no balloon must leave the ground unless the diaphragm ripcord rope is completely removed from the balloon. The flight also indicated that the use of the radio blow down may very well save a serious situation in which a balloon could be floating in the airplanes for a considerable length of time.

FLIGHT #26

Flight #26 was launched on July 21 at 1449 and used a Winzen double-wall Air Force balloon, #2-100-V-122, equipped with glass filament tapes, 11 meter antenna, and was packed with a taped aluminum girdle, a leather reinforced corset, and a new model appendix with four breather holes. The balloon weighed 234 pounds and was packed July 16. The expected ceiling for this flight was 83,000 feet and the flight duration planned was 48 hours. The purpose of the flight was to study the sunset and sunrise effects on a balloon containing a fractional content of ammonia in the inflation gas. The flight was a repetition of flight #24 and like that flight, a mixer for ammonia and helium was used, so that the inflation contained 70 pounds of helium and approximately 30 pounds of ammonia. The inflation was carried out by feeding ammonia directly from the ammonia cylinders into the mixer at a total pressure on the ammonia side of the manifold of 100 pounds. With the ammonia shut off, the same pressure gauge read 25 pounds, due to the helium flow through that portion of the mixer. The apparatus contained in gondola #11 used on this flight included a 1724 kc transmitter, #60, the usual Olland cycle with a one rpm drum, a 6420 kc receiver for command operation with two audio channels at 210 and 234 cycles. The gondola also contained the low altitude blow off, up camera, down camera, and horizon camera, and the balloon contained a top camera, mounted from the loading ring and set to begin running at 3000 feet elevation. The radio control was set to operate the blow down on the 210 cycle channel and to drop a 30 pound lead box containing cosmic ray plates on the 234 cycle channel. These plates were to be dropped with a standard parachute and would constitute ballast drop, if necessary, and would also give cosmic ray information about the day and night, or other time effects. The balloon car-

ried a new model appendix consisting of a closed cap which reached from the bottom of the balloon to the load ring with a small hole in the bottom through which the load rope could pass. This cap had four openings placed around it with side tubes built of $\frac{1}{4}$ mil V-film. The diameter of these tubes was 2 feet and the side arms were long enough to hang down below the load ring and almost completely closed off the openings. The gross load was 436 pounds and the inflation proceeded without any undue difficulty until a free lift of 54 pounds had been achieved. The weather was clear, and the ground wind 2-4 knots. The balloon was rigged with a 3000 pound top cord, with a modified top ring to take the extra large diameter.

The balloon was erected by walking up the line and then cutting it as high above the ground as possible. The launching proceeded without difficulty but it was observed that the top did not inflate properly and as the balloon ascended it was obvious that the top tie down rope had become snarled in some manner around the top ring, preventing the top of the balloon from erecting to its full length in the air. The balloon rose to 34,000 feet, at which time it burst and the load dropped. Eventually one of the two parachutes carried on the gondola opened, and carried the load to the ground. The load was followed to the ground by a cub tracking plane piloted by Magnus and all of the gear was recovered at impact. The balloon failed at 1549 and the impact was on the Kay Howe residence, $1\frac{1}{4}$ miles southeast of Reeves, Wisconsin, which is 9 miles southeast of Clear Lake. Recovery was made by the stake truck, and it was found as expected, that the top tie rope had taken a half hitch around the top ring and locked causing a failure.

Conclusions

This failure pointed out that it is unsafe to let the long top tie rope slide through the top ring as there is danger of snarling or catching

on the fabric of the balloon. Some difficulty was also encountered with the removal of the corset at launching and it was indicated that some improvements were necessary here also.

FLIGHT #27

Flight #27 was launched July 23, 1952, at 1537. It was a double-wall Winzen Air Force balloon, #2-100-V-127. The purpose of the flight was to repeat flight #24 to determine whether the effects observed on this flight were a consequence of adding ammonia to the filling mixture. The balloon was equipped with the standard instrumentation, with pressure data telemetered on 1724 kc. There was radio controlled command blow down and cosmic ray load flown as command operated ballast. Instead of clocks for timer control of blow down, the flight had a low battery voltage relay, which would terminate the flight when the batteries ran down. It had an up camera, a down camera and horizon camera. The appendix was the octopus type. It was believed that this appendix would minimize the intake of air which would allow the balloon to climb back to its full volume ceiling on the second morning. The maximum duration was to be 50 hours; the actual duration was 34 hours.

The launching weather was clear and the takeoff took place in a 25 knot wind in the lee of the damaged windscreen. Because the wind was so high we spent an hour nailing back some boards on the leg of the windscreen which we needed for this flight. The air displaced on this flight was 559 pounds and the free lift was 6.8% of the air displaced. The initial rate of rise was 700 feet per minute which increased to 990 feet per minute between 300 and 100 mb and 1420 feet per minute between 100 mb and ceiling. This increase in rate of rise has been found to be typical of ammonia balloons equipped with effective appendices. It is not entirely clear, at this time, that helium balloons with effective appendices do not also increase their rate of rise by this much. The balloon reached its theoretical ceiling of 83,000 feet at 1710. It floated quite level until sunset on the ground and began descending at 1950. Sunset occurred on the balloon at 2022, at which

time the balloon was descending fairly rapidly. At 2210 the balloon levelled off at an altitude of 65,000 feet. It floated level until 0200 on July 24 at which time it began to climb. The rate of climb did not increase appreciably at the time of balloon sunrise, but did appear to increase when the sun rose on the ground. The balloon levelled again at 79,000 feet at 0630 on July 24. It floated essentially level throughout the day on July 24, and at 2000 had descended to an altitude of 75,500 feet. This loss of altitude in over 24 hours was essentially what might be expected on the basis of leakage. After sunset, however, on July 24, the balloon began descending rapidly and at 2220 reached the altitude at which the low altitude blow down released the load. The fact that the balloon descended so rapidly on the second night can hardly be attributed to a leak, since the balloon itself floated for two more days before landing. It was seen descending at 2300 on the night of July 26. At the time of release, the balloon riptape was completely removed from the balloon and was recovered with the load. The peculiar descent of the balloon on the second night is believed at this time to have been due to ground conditions which caused the ammonia superheat to be lost. The meteorological situation is being investigated.

Because of the interesting balloon performance during this flight, it was decided not to drop the command ballast load until the morning of July 25. At this time Ray Maas took his command transmitter in the carry-all and attempted to operate this blow down from Huron, South Dakota, at 0930. It was not known to us that the load was on the ground at this time at Wessington Springs, South Dakota, approximately 60 miles from Huron. In spite of this fact, the command release operated properly. We believe the reason it was possible to operate the release on the ground is that in landing the riptape which contained the receiver antenna was spread out along the ground on top of the hill where the gondola landed.

Conclusions

The behavior of this needled ammonia flight closely paralleled that of flight #24. The descent for 15,000 feet at night occurred in the same way, with the balloon levelling off at a new stable altitude. In order to explain this behavior on the basis of stratosphere lapse rate alone, a 5-degree centigrade per 1000 feet positive lapse rate would be required. The remarkable behavior on the second night could be due to decreased ten micron radiation from the earth in the area underneath the balloon. If ammonia super-heat is really being produced, a solid bank of clouds would be definitely less effective in producing this super heat than the surface of the earth. The flight also showed the increasing rate of rise previously associated with ammonia flights. It doubled its rate of rise by the time it had reached ceiling. No difficulties were encountered in launching this balloon in a 25 knot ground wind. It was possible to operate the radio command over ground for a distance of 60 miles after the termination of the flight.

FLIGHT #28

Flight #28 was launched July 29 at 1312. It was a double-wall Winzen balloon #2-100-V-105. The purpose of the flight was to run a control experiment with pure helium to compare with the helium and ammonia flights, #24 and #27. The instrumentation was very similar to flight #27 with the same complement of cameras and the same arrangement for command operations.

The balloon was launched in a 25-30 knot wind. A jet stream had been present during the day, and it was learned that a General Mills balloon flown that morning had broken at 50,000 feet. In spite of the high launching wind and the jet stream, the launching and ascent to altitude proceeded very smoothly. The balloon did not show the increasing rate of rise of flight #27. The rate of rise increased from 750 feet per minute to 800 feet per minute as opposed to 700 feet per minute to 1420 feet per minute in flight #27. The balloon reached theoretical ceiling with a square corner, and floated absolutely level for 70 minutes, at which time it began descending at the rate of 50 feet per minute. This rate increased to 76 feet per minute at sunset and at an altitude of about 50,000 feet at time 2400, decreased again to approximately 50 feet per minute. The balloon reached the altitude at which the low altitude blow-down operated at 0420 on the morning of July 30. At about 2200, the telemetering signal was no longer intelligible at the University Airport. At this time we called various CAA stations and asked them to tune in on our frequency and place the telephone transmitter near their loud speaker. The stations tried were Lone Rock, Milwaukee, Eau Claire, and La Cross. The La Crosse signal was the best of the group, and it was possible to obtain altitude data from this signal with a stopwatch. The CAA people were very cooperative in this operation and actually made stopwatch measurements themselves, transmitting them to us via the CAA teletype network.

The signal obtained by the LaCrosse CAA station showed that the balloon had reached an altitude of 39,000 feet at 0345 on July 30. At 0420, the signal began giving many fast pips and at 0450 a very weak signal was heard, presumably from the load on the ground. Although the load has not been recovered, it is believed that it was released and landed on high ground in the vicinity of LaCrosse.

The balloon was recovered in Merignac, France. Assuming the release point of the load previously indicated, and the impact time for the balloon as observed by the finder in France, one comes to the conclusion that the balloon travelled 4200 miles in 87 hours, making an average speed of 50 miles per hour provided that the balloon travelled along a latitude line. It is to be observed that a rather strong jet stream of 100 knots or more was present at our latitude at the time of launching.

Conclusions

As a control for flights #24 and 27, flight #28, which was inflated with pure helium behaved quite differently than the other two. It did not increase its rate of rise by nearly as much as the other two flights. It did not float level during the night as did the other flights. The balloon showed the behavior which other double-wall Air Force balloons inflated with helium have indicated, namely, a descent at a constant rate after an hour of level flight at ceiling. This balloon apparently passed through a jet stream without any damage.

FLIGHT #29

Flight #29 was launched August 5, 1952, at 0919. It was a Winzen double wall balloon #2-100-V-121. It was equipped with a taped girdle, a valve in the balloon crown, and a standard appendix which was tied off before takeoff.

This flight is the first of a series designed to obtain flight constants for the motion of the balloon in the stratosphere. In order to interpret previous flights, and to design control equipment for balloon systems, it is necessary to know what rate of rise or descent will be produced by a given loss of lift. Experience in previous flights such as #24 has shown that balloons which have open appendices will take air, and after ballast is dropped will not climb back to their original theoretical ceiling. Therefore, in order to obtain the flight data, it is necessary either to have an effective appendix or to tie it off.

The maximum duration was to be 14 hours, and the actual duration was six hours ten minutes. Release took place by the aneroid blowdown. The balloon was equipped with a ballast-hopper gondola with sub-carrier transmitter on 1724 kc and Olland cycle pressure transmitter. The release of ballast or the control of valving was accomplished by means of signals transmitted to the command receiver #8-J and operated on 6420 kc. This command receiver is very narrow band (approximately one kc band width) with resonant relays operating on 210 cycles per second for valving and 234 cycles per second for ballast dropping. The telemetering was arranged in such a way that when control was established by radio a characteristic signal was transmitted back. After control had been maintained for approximately 30 seconds, the operation to be commanded would commence. At this

time a second signal would be superimposed on the telemetering to inform us that ballasting or valving was going on. The valve in the balloon crown had a diameter of $3\frac{1}{2}$ inches and had a calculated response such that at ceiling altitude the valve should allow 0.35% per minute loss of lift when it is being operated. This is the same control sensitivity that the ballast system has. At lower altitudes, the valve is relatively more effective - for example, at 30,000 feet the valve should produce a loss of lift of $2\frac{1}{2}$ % per minute.

The launching took place without incident in the northeast quadrant of the windscreen. The launching wind was approximately five knots. The balloon was weighed off relatively heavy, and ascended at the initial rate of 570 feet per minute. At 0940, command of the valving was established at an altitude of 12,000 feet, and valving took place for 54 seconds. In the period between 0940 and 1005 the rate of rise was 480 feet per minute. The balloon would normally have increased its rate of rise in this period but instead showed a decrease due to the valving. At 1005, altitude 24,000 feet, valving again took place for 124 seconds. The rate of rise between 1005 and 1042 was 490 feet per minute. It is believed that the valving kept the balloon from increasing its rate. At 1042, altitude 42,000, valving took place for 460 seconds and the rate of rise was decreased to 120 feet per minute. By 1146 the balloon had risen to 50,000 feet, at which time 13 pounds of ballast were dropped. This ballast drop increased the rate of rise from 120 feet per minute to 380 feet per minute. At 1150 the telemetering signal became unintelligible and the balloon was in the vicinity of Eau Claire, Wisconsin. Because it was impossible now to determine what was being done to the balloon it was not possible to continue the experiment.

For this reason we allowed the balloon to ascend to theoretical ceiling in the belief that it would burst. It reached an altitude of about 86,000 feet, somewhat above its theoretical ceiling. Instead of bursting, however, the balloon began descending, and between an altitude of 79,000 feet and 32,000 feet, had a rate of descent of approximately 780 feet per minute.

The load was recovered at Stratford, Wisconsin, immediately after impact. The balloon, which was apparently not demolished by the riptape, was found near Walford Station, Ontario, on the night of August 5. It is believed that the flight constant experiment could have been completely carried out on this flight had the telemetering continued to operate properly.

Conclusions

Radio command of ballast and valving was very satisfactorily accomplished in this flight. Some flight constant data was obtained because of the change in rate produced by dropping ballast and by valving. Although the balloon reached theoretical ceiling with a tied-off appendix at the rate of 380 feet per minute, it did not burst, but apparently opened a relatively small hole. In future experiments of this sort, we will endeavor to get the balloon to altitude and allow it to float back over a telemetering station before attempting to measure flight constants. It was probably a mistake to valve gas when the balloon was in the region of high altitude winds, because this made the balloon spend more time in this region and caused it to get relatively far away from us.

FLIGHT #30

Flight #30 was launched on August 6, 1952, at 0922. It was a Winzen double-wall balloon, #2-100-V-90, with a standard appendix and rayon cloth-covered girdle. The purpose of the flight was to check balloon performance with a heavy load and needled ammonia. The load consisted mainly of cosmic ray gear (Sophie Oleksa's difference experiment). The maximum duration was to be 10 hours and the actual duration was 3 hours 6 minutes. Termination was by aneroid blowdown. The instrumentation consisted of a small gondola without cameras, but with 1724 kc sub-carrier telemetering. The balloon was launched between intermittent showers - the sky was completely overcast, and before and after the launching there was considerable rain. The launching wind was 8 knots and the flight was delayed four hours because of downpours. When the balloon actually took off it was raining, but very little rain occurred during the inflation.

Several things happened during this operation which could have spoiled the flight before launching. First the bubble became quite tight before all of the gas was in the balloon. Had this not been corrected, it is likely that the bubble would have burst on the ground. In packing the balloon, the gores apparently had not been carefully straightened around and the volume of the bubble was restricted. We erected the balloon before all of the gas had been put in to keep the bubble from becoming tighter.

Second, the ladder from which the gondola was suspended during rigging was pulled relatively near the balloon and it was realized at the last minute that when the balloon erected it would have struck this ladder. Fortunately it was removed in time.

Third, in adding up the weights of the flight the inflation was computed without including the free lift. This was discovered before the inflation hose

had been pulled and the proper amount of gas was inserted.

The last thing which could have caused failure was that because of the damp ground, the tie down screws did not hold nearly as well as they do in dry earth. Don Hanson became suspicious of this and just before the balloon erected he installed a second ground screw at the base of the balloon. When the top line was cut and the balloon erected, the first ground screw pulled out but the second one held.

Only 15 - 20 pounds of ammonia were injected because of the fact that a new ammonia cylinder was present on the manifold, and liquid came over into the injector. This liquid caused freezing up of the injector.

After launching the balloon did not show the increasing rate of rise previously associated with ammonia flights. It is believed that this was due to the fact that the radiation which the balloon saw coming up from the earth had a lower characteristic temperature produced by the presence of the complete overcast. The rate of rise increased from 740 feet per minute to 865 feet per minute, essentially what one observes in a pure helium inflation, as opposed to approximately doubling the rate of rise, as occurred in flight #27. After reaching ceiling, the balloon floated level for approximately 10 minutes, then began descending. After reaching an altitude of 64,000 feet, the rate of descent became approximately constant and between 64,000 feet and 24,000 feet the rate of descent was 1300 feet per minute. At this time, the aneroid blowdown released the load. The equipment was recovered near Pepin, Wisconsin, and the balloon near Wheeling, Illinois. The cosmic ray gear and the telemetering gondola were suspended from a boom in this flight. This boom was bent almost 90° from the shock of the parachute opening at low altitude. All evidence of acceleration inside the cosmic ray sphere showed that the greatest shock occurred when the parachute opened, rather than on impact with the ground.

Conclusions

The principal conclusion from this flight is that the increase in rate of rise observed in most ammonia flights may disappear when the earth radiation is characteristic of a cloud layer rather than the earth itself. The reason for the failure after floating for 10 minutes at ceiling is not understood at this time, but it is believed to be due to a hole produced after the balloon reached ceiling. It is, however, possible that a leak was present which kept the rate of rise from increasing and which finally brought the flight down. It is not known in this flight whether the girdle acted as an automatic appendix because the balloon was never in visual contact after launching due to the overcast.

FLIGHT #31

Flight #31 was launched on August 12, 1952, at 0917. It was a Winzen 1 $\frac{1}{2}$ -mil balloon, #150-V-115, equipped with an octopus appendix. Because of previous difficulties with the corsets, this corset had a $\frac{1}{2}$ inch foam rubber protective layer beneath it. This was the second flight in a series to obtain flight constants and like flight #29 was equipped with a command receiver, 1724 kc transmitter, and Olland cycle. The telemetering was by Lofam. It had up, down and horizon cameras. In addition, the flight had a low battery voltage blowdown. It was planned to have the balloon rise to ceiling and valve gas and return to a position above the tracking center before command operations took place. Unfortunately, the antenna ball never dropped and as a consequence, no telemetering data was obtained to indicate the altitude or to inform us about our command operations. We did attempt to valve and to drop ballast during the flight several times and since the day was clear altitude data was obtained by double theodolite, one of which was set up at Flying Cloud Airport. The duration of the flight was to be 14 hours, and the actual duration was 14 hours. Release took place by means of the command transmitter. Instead of having the ballast arranged to be continuously dropped, this flight carried a sequence ballast dropping mechanism by means of which an increment of ballast was dropped each time the radio control operated. The sequence of ballast was the following: 10, 20, 30, 10, 20, 30 pounds. The idea behind this arrangement was to allow the balloon to reach ceiling then to valve gas to make the balloon descend to 50,000 feet. At 50,000 feet we planned to drop 10 pounds of ballast and observe the rate of rise. We hoped to repeat this with 20 and 30 pounds and to have the balloon reach ceiling before sunset. After sunset we desired

to drop first 10, then 20, then 30 pounds to bracket the magnitude of the sunset effect. Because of the presence of a jet stream at 150 mb, the balloon did not get back over the tracking center until afternoon and without the telemetering to indicate the success of the command operation, we were able only to drop one bag of ballast. It was therefore impossible to obtain the flight constants in this flight. We did attempt to drop ballast throughout the afternoon and after sunset, but the barograph does not give a definite indication of success. One ballast bag had been dropped in the air at an unknown time. The balloon survived the sunset and was released by timers at the planned duration.

The balloon and load were both recovered in Wisconsin, near Maiden Rock.

Conclusions

Although the balloon performance was good, failure of the antenna dropper kept us from obtaining flight constants. The failure was due to the bellows developing a leak after the time that it was tested, in a bell jar. After flight #33 it was determined that this failure was caused by acid soldering flux dissolving the bellows from the inside. The flight serves to give another example of the sunset effect on a $1\frac{1}{2}$ -mil balloon.

FLIGHT #32

Flight #32 was launched on August 19 at 0751. It was a Winzen 1½-mil balloon with an octopus appendix, fiber acetate tapes, nylon cloth covered girdle, and radio command valve in the balloon apex. The purpose was to repeat Flight #31. The maximum duration was 28 hours, and the actual duration was 19 hours 20 minutes. Release took place by the aneroid blowdown. The flight had a gondola equipped as in flight #31 with the exception of the horizon camera.

The inflation was pure helium. Launching took place through an overcast, and an east southeast wind of approximately five miles per hour. Because the wind was so low when the balloon was laid out, we got in the wrong leg of the windscreen, and it was necessary to walk the balloon away from the windscreen before ripping the diaphragm and removing the corset. Because of our past experience with valves in the top, on this flight we cut the tie line to the inner tire short, and erected the top slowly by means of a rope which passed through the load ring on the top of the balloon. This operation went quite smoothly, and there was no hitch in the launching. The rate of rise increased slightly during the ascent, but did not increase as much as with an ammonia inflation. The balloon reached theoretical ceiling and floated level for one hour, after which time it began descending at a rate of fifty feet per minute, as has been observed in a number of other flights. This behavior has been named the Howell effect, since similar behavior with Winzen balloons has been experienced by the Tufts College group, working on the Moby Dick operation. After the descent commenced, the balloon was almost overhead, and we attempted valving seven times. After these attempts, we became convinced that the valve was not being operated, in spite of the fact that the telemetering implied that voltage was being applied to this valve.

Subsequent examination of the wires connecting the valve showed that cold fracture had split the insulation off and may have allowed these wires to short. The radio operation of the relay, however, was accomplished without difficulty and at will. At 1400, when it was realized that valving was not being accomplished the first ten pound ballast drop was performed by radio command. This ballast drop caused the balloon to cease descending and to level off immediately. At 1430 the second ballast drop was accomplished, releasing twenty pounds of steel shot. The balloon rose approximately $\frac{1}{2}$ milibar and continued on its level trajectory.

Examination of the balloon through the telescope, and also through the medium of the up pictures, showed that in spite of the octopus appendix, the balloon had taken in air on its slow descent, and was completely full at the time the ballast dropped. As has been previously explained, a balloon which is full and has mixed air with helium will gain only a small amount of altitude when ballast is dropped. As a consequence of this, the first ten pound ballast drop may have been more than would have been required to stop the descent of the balloon, since the second ballast drop did not cause the balloon to rise, and indicated that the air and helium had become completely mixed. It can be stated, however, that ten pounds or less free lift will produce fifty feet per minute rate of descent. It can also be concluded that three hours at a pressure of forty mb is sufficient time for the mixing of air and helium to take place. The balloon was allowed to float level at fifty mb until 1900 at which time thirty pounds of ballast were dropped. The balloon rose in pressure by four mb in a period of about three minutes and levelled off again. From this time on, we continued to attempt the ballast drop of the last three bags but were unable to tell from the telemetering whether we accomplished

the control. Apparently the relay indicating on the telemetering record the effect of command operations had failed. The balloon showed only a small change in altitude at sunset, and telemetering contact was lost at 2220. The barograph record, however, showed that level flight continued until 2315 at which time the balloon began descending rapidly. The load was released by the aneroid blowdown at approximately 0130.

The balloon and gondola, with all hardware, were recovered in Wisconsin.

Conclusions

The principal information learned on this flight was the following; even with the octopus appendix, a balloon descending at fifty feet per minute will take in air. It is clear that the mixing time at 40 mb is quite short, and air taken in will be mixed in the time of three hours or less during the day. An upper limit to the free lift responsible for fifty feet per minute rate of descent was found to be ten pounds, or two per cent of the air displaced.

The so-called Howell effect, which causes a balloon to begin descending after approximately an hour of level flight, can be compensated for by a relatively small expenditure of ballast. In this case, ten pounds was more than enough. At the time of this flight, we became convinced that the Howell effect comes about because of the loss of a fixed amount of lift, and is not produced by leaks. The exact explanation for the effect, however, is not yet known.

FLIGHT #33

Flight #33 was launched on the 21st of August at 0627. It was a Winzen balloon #150-V-156. It had one inch fiber acetate tape and was equipped with an 11 meter antenna and a standard 50 inch straight appendix. The aluminum girdle was taped and because of some trouble with corsets we had installed foam rubber under this corset on this flight. The purpose of the flight was to try to determine whether the so-called Howell effect could be alleviated by using dry ice ballast. As has been pointed out in previous flight reports, the Howell effect is that behavior of a balloon which is characterized by a slow descent starting after the balloon has been at ceiling for approximately forty minutes to an hour. At the time of this flight it was believed that the Howell effect was caused by some process which made the balloon lose a fixed amount of lift forty minutes after reaching ceiling. There had been some evidence that the time required for the gas in the balloon to warm up represents about forty minutes. The balloon gas reaches ceiling cold because as the balloon ascends the gas is adiabatically expanding and acquires an equilibrium temperature lower than the temperature of the plastic. Since the gas is warming for this length of time a balloon which is floating at ceiling altitude will continue to valve and even moderate leakage will not cause it to descend during this initial period. Many flights, however, have been observed to descend at the end of the warming period at a reasonably slow rate - perhaps 25 to 50 feet a minute. Because of the fact that the intake of air during this descent will affect the rate and because at this time it was not clear what the relation between free lift and rate of rise was, it was believed to be worthwhile to perform an experiment with a moderate expenditure of ballast at the time the Howell effect occurs. This was accomplished by hanging on the load a block of dry ice weighing $22\frac{1}{2}$ pounds. Laboratory tests had indicated that such a block of dry ice at the pressure encountered in the balloon flight would evaporate in a period of four to six hours.* The

*Subsequent experience has shown the evaporation rate to be slower than this.

expected duration of this flight was 12 hours. The actual duration was 12 hours. Release took place by means of timers. The flight was equipped with standard instrumentation including a 1638 kc transmitter with an Olland cycle and a standard antenna dropper. The launching weather was clear and the launching took place in a north northwest wind of two to three knots and the launching proceeded very smoothly except that too much gas was put into the balloon before weigh-offs were made and in order to have the proper weigh-off 20 pounds of lead shot were hung on at the last minute.

In addition to the balloon instrumentation, the flight carried three pounds of plates for a cosmic ray experiment and Sophie Oleksa's carbon difference cosmic ray experiment. The cosmic ray gondola and the instrumentation gondola were hung on a balance bar as had been done in previous flights in which we used cosmic ray equipment as pay load. The gross lift was 552 pounds with 66 pounds free lift and 629 pounds of air displaced. Shortly after take off it became clear that no radio signal would be received and the cause of this was attributed to a failure of the antenna dropper. It was later determined that this was the cause of the failure of the telemetering. Examination of the antenna droppers showed that on some of the recent models the soldering of the sylphon had been done with acid core flux which got inside the sylphon and corroded it so badly that it caused a failure at the bend of the convolution. The trouble was corrected after this flight and it did not occur again. Because of the lack of telemetering it was necessary to obtain altitude data by means of double theodolite bearings. We immediately got two theodolites on the balloon from University Airport and from Flying Cloud Airport and because the winds

were light were able to theodolite the balloon for essentially the entire duration of the flight. It was also possible to get altitude data from the thermo-barograph which gave a good record. Examination of the altitude data after the flight showed that the Howell effect had indeed been alleviated by the use of the dry ice ballast. This is a clear indication that the loss of lift responsible for the Howell effect is quite small since the rate of evaporation of the dry ice was so low that during the period in which the Howell effect occurred, a matter of perhaps ten minutes, not more than a pound of dry ice would have been sublimed. The flight showed essentially a constant rate of rise to theoretical ceiling with a relatively square corner and floated level until released by timers. The altitude data obtained from double theodolites and from the barograph agreed quite well and showed that the balloon descended less than 5000 feet during the day.

Conclusions

The standard appendix used on this flight was adequate at the rate of rise encountered for keeping air from being intaken into the balloon during the ascent. The balloon actually reached theoretical ceiling showing that very little if any air had been intaken and floated level throughout the day. Other balloons which had the air eliminated by effective appendices have shown a descent after 40 minutes of level flight at ceiling. Because of the dry ice ballast used on this flight, flight #33 did not show this behavior and it is therefore believed that the ballast required to compensate for the Howell effect is quite small. The fact that the flight maintained theoretical ceiling after the dry ice had evaporated indicated that this balloon did not have appreciable leakage.

FLIGHT #34

Flight 34 was launched on the 28 of August, 1952, at 1814. It was a Winzen one mil single-wall balloon made of DE 2500 resin with one inch fiber acetate tapes. It was equipped with a 36 inch standard appendix and had an 11 meter antenna in it. There was a nylon cloth covered girdle and the corset was equipped with foam rubber because of previous troubles with it. The balloon was launched before sunset in a 6-10 mile per hour west southwest wind and the sky was clear. The launching took place smoothly without incident. The purpose of the flight was to determine the effect of sunset occurring on the balloon while the balloon was rising. For this reason the launching time had to be accurately determined and we got the balloon off within a minute of the time that we had anticipated launching. It was desired that the balloon should get through the high wind region before sunset occurred on it and it actually turned out that the sunset occurred on the balloon at an altitude of 50,000 feet.

The scheduled duration of this flight was 21 hours and the actual duration was 20 hours and 30 minutes and release took place by means of a timer. In addition to the cosmic ray standard pack of plates we used as a pay load on this flight, John Naugle's plate mover and recorder which furnished us with additional information about the balloon altitude. The standard instrumentation consisted of a 1638 kc transmitter with Olland cycle and standard antenna dropper. Because there were separate gondolas on this flight they were flown with the balance bar as had been done on previous flights such as flight #33. The gross lift was 344 pounds with 52 pounds of free lift and 393 pounds of air displaced. The initial rate of rise was 790 feet per minute which increased between 300 - 100 mb to 980 feet per minute. The initial characteristics of the time altitude curve showed an increasing rate of rise charac-

teristic of balloons which start at this rate, but this rate, instead of continuing to increase was somewhat decreased by sun setting on the balloon. Similar flights that had 980 feet per minute between 300 and 100 mb, would have increased approximately to 1050 or 1100 feet a minute between 100 mb and ceiling. This flight, however, showed a rate of rise of 845 feet a minute between 100 mb and ceiling. The flight reached ceiling with a square corner and floated level for approximately 40 minutes. As in flight #33 dry ice had been added to the load in order to compensate for the Howell effect. In this case the dry ice, which was carried as a single chunk was not adequate in its rate of sublimation to completely eliminate the Howell effect. Consequently the balloon descended approximately five to eight thousand feet before the dry ice sublimation rate caught up with the Howell effect and caused the balloon to level again. It floated essentially level all night and climbed very slightly at sunrise. It was released by timers at the scheduled time. In flight #34 there were a number of methods for measuring the balloon altitude. The flight had a low altitude barograph, a high altitude barograph, a separate Olland cycle, a Wallace and Tierman gauge in the cosmic ray equipment and it was possible to get altitudes from double theodolite bearings. All methods of determining the balloon altitude agreed very well during the ascent up to the time the balloon reached ceiling. At this time the barograph stopped and it was not possible to get either high or low altitude barograph readings after that. All later times during the flight the Wallace and Tierman gauge read somewhat higher pressure or lower altitude than did the Olland cycle and the down pictures gave an altitude intermediate between that measured by the Wallace and Tierman gauge and that measured by the Olland cycle. To indicate the magnitude of this discrepancy, the maximum discrepancy that occurs corresponds to a measurement of 21 mb pressure by the Olland cycle and 25 mb pressure measured by the Wallace and Tierman gauge with the down picture readings in between these

two. It is not clear where this discrepancy in altitude arises. Investigation afterwards indicated that the calibration procedures were carried out with appreciably higher accuracy than would be indicated by this agreement.

During the ascent of the flight a rather interesting phenomena was observed. The balloon passed through a region in the atmosphere about 20 to 30 thousand feet where the air was super saturated and the block of dry ice which was used to minimize the Howell effect, created a vapor trail approximately 5000 feet long. The very slight rise in altitude at sunrise gave an indication of complete mixing of air which the balloon took in as it descended. The pressure was relatively low, approximately 20 mb, and mixing could take place throughout the whole night. The load on this flight was not immediately recovered. The balloon was found by an air search in the vicinity of release point around Princeton, Minnesota, but the gondolas could not be spotted. After an intensive air and ground coordinated search the gondola was discovered approximately a mile away from the balloon.

Conclusions

This method of allowing the sun to set on a balloon during ascent has been demonstrated by this flight to be sound. There apparently was no damage to the balloon during its ascent into the stratosphere after sunset. At night the evaporation rate of dry ice is not quite adequate to immediately compensate the Howell effect but it was shown in this flight that it did finally catch up. It is believed that if the dry ice were powdered instead of being flown in a block it would probably be adequate to keep the flight level at the time when the Howell effect sets in. By comparing the rate of rise before and after sunset in this flight with the rate of rise at the same altitudes observed in a regular daytime ascent it is possible to estimate the magnitude of the observed sunset effect on this balloon. It is natural to believe that this observed

sunset effect could be appreciably less than the sunset effect of a balloon floating level at ceiling because of the fact that the rather high rate of rise should appreciably increase the conductive cooling of the balloon and thereby decrease super heat. Assuming that the drag at sunset is essentially all thermodynamic in comparing the rates as indicated previously, one obtained the value for the sunset effect of 4%. The assumptions that were made were that the 845 feet a minute which occurred after sunset corresponded to a day flight with 1100 feet a minute rate of rise at this same altitude. It was assumed that the relation between free lift and rate of rise was proportional to the rate of rise to the $3/4$ power and the sunset effect could then be calculated to be 4% of the air displaced in the flight. It is thought that a more sophisticated calculation based on the total drag, including the aerodynamic drag is not justified in view of the fact that the day flights which can be compared with this night flight show some fluctuation in rate of rise and 1100 feet a minute between the altitudes corresponding to 100 mb to ceiling represents an average of these flights. It is believed that the 1100 could be replaced by the value as low as 950 or as high as 1200 or 1250.

FLIGHT #35

This flight was launched on September 3, 1952, at 0929 for the purpose of measuring balloon flight constants by valving gas and dropping ballast and measuring the response of the balloon in altitude. The balloon was a Winzen 1 mil cell #73-100-V-172 and was constructed with acetate tapes. The balloon weighed 132 pounds and was packed August 26 with a nylon cloth covered girdle and a corset protected by sponge rubber in the manner adapted for recent flights. This balloon was also equipped with an electrically operated valve which was inserted into the balloon about 3 feet from the crown. This valve was constructed like that used on flights #31 and #32, but the diameter of the opening was increased to $10\frac{1}{2}$ inches so that the volume of flow would be sufficient even at lower pressures near the balloon ceiling to maintain control. The valve mechanism was inside the balloon, and the valve was secured to the fabric with O-rings and metal clamping rings. The valve was placed just far enough from the crown so that it could be fitted between adjacent tapes. The three electrical leads were secured to the top ring and then passed down the balloon, being taped in place on one of the load tapes. Photographs and drawings of this valve are given in the instrumentation section. The gondola contained instrumentation for a 24-hour flight, including a 5 watt MOPA 1746 kc transmitter and a 6420 kc command receiver, up and down cameras, low altitude cut off and a blinker beacon for night operation. Instead of timers, a low voltage blow down was used to separate the load when batteries had run down. A Strobe-lite was rigged with a large reflector to illuminate the balloon at night and was triggered every five minutes by the up camera. The gondola weighed 270 pounds complete with ballast. The ballast system consisted of a 6 step increment release which dropped successively, steel shot in 10, 20, 30, 10, 20, 30 pound lots. The ballast was

released by squibs which were fired by a stepping relay which was controlled in turn by the command receiver. Command cut down could be achieved by advancing the stepping relay to the 8th position following the release of all the ballast.

This flight was laid out and launched without any difficulties with clear skies and a 10 mile per hour southwest wind. Precautions were taken during inflation to prevent damage to the balloon by the rather heavy valve assembly in the top. This valve in the packed balloon hung against the top of the girdle. To avoid pulling the valve against the girdle and damaging the plastic too severely, the upper end of the balloon was detached, and the balloon was erected earlier than normal after about 100 pounds of lift in excess of the balloon weight had been obtained. The 3,000 pound nylon top line was cut about 3 feet from the crown, and the balloon was walked up with a handling line fed through the top ring. The stresses were not great, and no apparent damage developed because of this. The handling line was then removed as the balloon was bobbing about somewhat behind the windscreen and attempts to restrain it could have resulted in damage where the valve was placed. The balloon was launched by just picking up tension in the gondola without actually having it lift clear of the ground and then cutting the load lines. The appendix was taped off at the load ring, and it was expected that the valve would be opened to exhaust the free lift gas before the balloon reached ceiling and control would then be realized with the valve and ballast drops. On the ascent the antenna was late in dropping and telemetering came on at 20,000 feet. The girdle remained on the balloon and apparently slipped down in a normal manner. However, attempts to operate the valve by command control proved unsuccessful, apparently caused by radio interference from the valve motor. The command operation was successful in actuating the control mechanism in the

prescribed manner, but when the valve motor was turned on, control ceased. It was clear that the valve opened about 1/4 of an inch and closed again immediately. If the command control was held down, the valve would merely oscillate open and shut over this range, and although control was begun early in the ascent, no perceptible slowing down of the balloon resulted. When it became apparent that the balloon would burst at ceiling, it was decided to separate the load to avoid the large free fall and consequent stresses on opening of the parachute at 30,000 feet. Accordingly, the stepping relay was actuated to release the ballast, and the load was cut from the balloon at about 76,000 feet. The parachute was followed down to 29,000 feet by theodolite and telemetering contact was achieved almost to the ground. The load was found at Pepin, Wisconsin. It was ascertained that improper installation of a by-pass condenser was the cause of the noise interference from the valve motor.

Conclusions

It is obvious that the radio control devices need further development, particularly that shielding of the motor leads on the balloon and careful radio shielding of the motor are essential. Also, a more thorough radio control check out is indicated at the launching site.

FLIGHT #36

Flight #36 was launched the 15 of September, 1952, at 0919. It was a Winzen one mil, #150-V-116, with a nylon girdle and a rubber protected corset. It was equipped with a new type appendix called horse tail appendix. At the time that this flight was made it was realized that the appendix problem is perhaps the central problem in understanding balloon operation and in producing sustained flight. A number of flights have indicated that air intaken through an open appendix or even a standard appendix could be responsible for so greatly altering the characteristics of the flight as to make the detailed analysis of the flight almost impossible. Further reason for desiring a more effective appendix was the fact that the Howell effect as yet not completely understood could possibly be caused by the fact that the air could be taken into the bottom of the balloon at the moment the valving due to warming of the gas ceases. This could presumably take place through strong turbulence or turbulent conditions at the bottom of the balloon. Another possible explanation of the Howell effect is that change in shape occurs after the balloon has stopped valving and this change in shape is responsible for the loss of volume, loss of lift and rate of descent. The appendix which was used in this flight was attached to the balloon at a point about the position of the girdle, that is, about a third of the way up from the bottom of the balloon. It hung down vertically and was terminated at a point below the bottom of the balloon so that after valving the balloon would have a slight super pressure. We felt that an experiment with this type of appendix would throw some light on the Howell effect and might possibly eliminate the intake of air during balloon descent. The balloon was equipped with standard instrumentation and had a 1638 kc transmitter with Olland cycle and standard blow down box. It was inflated on a clear day in a west northwest 20 mile per hour wind at the

University of Minnesota airport. The gross load in this flight was 311 pounds with 50 pounds of free lift and 420 pounds of displaced air. Despite the 20 mile per hour wind the launching went smoothly and the balloon took off without any trouble. The horse tail appendix used in this flight was 66 feet long and was attached just above the girdle by heat seal and polyethylene tape. It was six feet in diameter and made of one mil material. The part of the appendix that extended below the balloon was rolled up near the girdle during packing and was expected to fall out of the girdle and unroll in the air. The flight was visible through the telescope and theodolite all the time and it was observed that the polyethylene roll did fall out of the girdle but it never did unroll. Consequently the balloon was essentially tied-off. It ascended to ceiling as a tied-off balloon and burst at exactly theoretical ceiling. The gondola free fell from altitude to 30,000 feet. At 30,000 feet the blow down box apparently operated blowing the squibs. However, most of the balloon had flapped itself loose so that there was only a small amount of pulling force left between the gondola and the balloon when the squibs fired.

The parachute ripcord apparently pulled loose releasing the chute but the balloon ripcord did not function properly and continued to tow the remainder of the balloon down after the gondola. The parachute had apparently wound itself around the balloon ripcord and never opened so that the gondola free fell from 30,000 feet with only the kite tail action of the balloon as a parachute. The parachute shroud lines were not completely pulled from the parachute pack, there being over $\frac{1}{2}$ the length of the lines still contained in the pack. The six feet length of the shroud lines that did loosen themselves from the pack were completely spiraled around the balloon ripcord. All members of the gondola frame were bent except the top horizontal frame members. The transmitter rack was bent rather sharply some three inches out of a straight line. One of the four upright legs was completely snapped off just below the top frame member gusset. The damage

to the equipment was rather extensive because of the free fall. The balloon showed an increase in rate of rise now believed to be characteristic of balloons that do not take in air, the ~~rate~~ from 0 to 30,000 feet, the velocity was 890 feet per minute. Between 300 and 100 mb or between 30,000 and 53,300 feet, the velocity increased to 1060 feet per minute. Between 100 mb and ceiling, the velocity reached a value of 1260 feet. Between 30 mb and ceiling, which was 15 mb, the velocity acquired a value of 1440 feet per minute, 1.8 times higher than the velocity at take-off. The load was followed to the ground by Magnus in the aircraft and was immediately recovered by Jim Magnus and the two men who went out in the truck.

FLIGHT #37

Flight #37 was the second of five flights which finally led to the development of a successful appendix. Flight #37 was launched on the 17th of September, 1952, at 0958. It was a Winzen 1½ mil balloon made of DE 2500 resin. It was balloon #150-V-155. It had a taped girdle, 11 meter antenna and a corset protected by foam rubber. It was the second flight of the horse tail appendix and the appendix was similar to that flown on flight #36 with the exception of the fact that the appendix was completely unrolled on the take off so there was no chance for it to become tangled and cause the balloon to burst. The horse tail appendix was attached as before by taping with polyethylene tape into an elliptical hole cut in a position just above the position in which the girdle finds itself just after take off. As in flight #37 the horse tail appendix was the only appendix and the bottom of the balloon is tied off. Maximum duration of the flight was to be 24 hours, the actual duration was 8 hours and 45 minutes. Release took place by means of the low altitude blow down.

Flight 37 was equipped with standard instrumentation including a 1638 kc transmitter, Olland cycle, blow down box and cameras and so forth. It was launched into an overcast sky with a 9 - 12 mile per hour north wind at the University of Minnesota airport, behind the windscreen. The gross lift was 360 pounds with 48 pounds of free lift, 420 pounds of air displaced. The initial rate of rise was 880 feet a minute which increased to 980 feet a minute by the time the balloon reached ceiling. The time altitude curve for this flight looks normal with an increasing rate of rise up to the point where it reaches theoretical ceiling. At this point the balloon was traveling approximately 1000 feet a minute and began descending immediately at 1000 feet a minute for 4000 feet at which point it established a rate of descent of approximately 130 feet a minute. This rate of descent

was maintained from an altitude corresponding to a pressure of 20 mb to an altitude corresponding to a pressure of 40 mb, at which time the rate of descent decreased slightly, and at an altitude corresponding to a pressure of 100 mb as the rate of descent increased again. The average rate of descent from 20 mb to 200 mb was also 130 feet a minute. The balloon reached 220 mb at the time of sunset and began descending very rapidly, struck the low altitude blow down ten minutes later and was released in this fashion. The behavior of this balloon after reaching ceiling, namely that of descending rapidly for a few thousand feet and then establishing a slow rate, was first observed in this flight. The exact mechanism whereby the balloon lost lift at peak altitude is not definitely established. Examination of the up pictures, however, did show that the appendix had a loose tape hanging at its periphery. One of the pictures seems to indicate sunshine coming through a hole in the top of the appendix. It seems that the most reasonable explanation for the loss of lift which happened upon reaching theoretical ceiling was that at this instant the appendix, which is attached at the point where the cone joined the sphere, became ruptured and valved out extra lift. It is easier to understand the behavior which follows this point, that of rapid descent followed by a slow constant rate. If a fixed amount of lift is lost from the balloon which is at ceiling and which has in it gas which has been cooled during the fast rise of the balloon, the balloon can drop rapidly compressing this cold gas adiabatically until its temperature rises to the equilibrium temperature which it would have acquired had it been subjected to sunlight and allowed to reach equilibrium. In the case of this flight, the drop in altitude was 4000 feet. With a stratosphere which has 0 lapse rate this corresponds to a relative warming of the gas of 16.4°C. One would expect that in the five minutes in which this happened, some warming would also occur because the gas is colder than its equilibrium

and from the 40 minute time constant normally observed one would estimate this warming as 1.6°C . This gives a total warming during the descent through 4000 feet of 18°C or a fractional change in temperature from $7\frac{1}{2}\%$ to 8% . This would indicate that when the balloon reached ceiling, this 8% deficit in temperature would appear as thermodynamic drag. Since the balloon took off with 11.4% free lift, one would therefore expect it to have $11.4 - 8$ or 3.4% of aerodynamic drag at altitude. Using the constants in the equations for free lift vs. rate of rise as determined by flights following this one, one would have come to the conclusion that this balloon should have had 3.3% as aerodynamic drag and 10% thermodynamic drag as it approached ceiling. These figures are in very good agreement with 3.4% aerodynamic drag observed and 8% thermodynamic drag observed from this change of temperature. This comparison does assume that the free lift that the balloon has on the ground does not increase by increased absorption of ultra-violet at high altitudes. It gives a good indication that a balloon which has reached its ceiling even with as light a load as 400 pounds air displaced, has mostly thermodynamic drag and only a small amount of aerodynamic drag. The changing rate of descent that the balloon experiences over the seven hours it is descending after reaching altitude cannot be explained in detail since one is inclined to believe that the appendix had a hole at the point of attachment on the balloon. The up pictures from this flight were extremely good and showed details of the appendix and the size of the balloon at all times during the flight. It is definitely established that as the balloon descended an appreciable quantity of air was intaken. The last pictures before sunrise were at about 200-250 mb and can be compared with the corresponding pictures during ascent. The pictures during descent show the balloon is very much larger during descent than during ascent at the same pressure.

Conclusions

This flight showed the first good evidence for the drag of the balloon in the stratosphere being almost entirely thermodynamic. It was a step in the development of a successful appendix and gave some indications that the attachment of the appendix is rather important and in this case it was very probable that just taping the appendix on with glass tape for support is very probably not adequate at points of the balloon where the stress is as high as where the cone joins the sphere. A rather interesting phenomenon was observed during the telemetering of this flight. Before sunset the balloon was beyond the line of sight for approximately two hours and also after sunset. There was no trouble in reading the telemetering data but extremely strong fading occurred probably because of interference of the skyway and refracted line of sight wave. The fading was very regular showing a sinusoidal effect in the signal strength at the receiving station. It was presumed that this effect may have been a result of a change in the differential path length between the skywave and the groundwave. The effect could be the result of one of several things. One possibility is the motion of the ionosphere vertically, another possibility is the lateral motion of the balloon. The computation based on the period of fading of the known height to the ionosphere and known distance to the balloon was made. Assuming that the effect was a result lateral velocity of the balloon, the velocity is calculated at between 10-20 miles an hour over the whole period. These results seem to indicate that the fading was not a result of the balloon movement as the calculations do not agree with the known wind speeds at the altitude flown. It does seem reasonable to conclude that the interference fading was the result of ionospheric motion or disturbances.

FLIGHT #38

Flight # 38 was launched on the 22 of September at 1047. It was a Winzen double-wall,^{#2}2-100-V-87. It was equipped with a horse tail appendix as flights #36 and #37, nylon cloth covered girdle and a valve in the top, a rubber padded corset as well as an 11 meter antenna. The purpose of the flight was to measure flight constants with the horse tail appendix. In spite of the rather disillusioning experience with the horse tail appendix on flights #36 and #37, it was thought to be worthwhile to try such an appendix on a flight constants experiment with the hope that the appendix would be more effective at keeping out air than would a standard appendix. The scheduled duration of the flight was 24 hours, the actual duration was one hour and 32 minutes. The cause of termination was that the balloon burst on reaching ceiling. The balloon was equipped with standard instrumentation including a 1746 kc transmitter, Olland cycle, #8-J receiver on 6420 kc and provision to operate ballast bags 30, 20, 10, 10, 20, 30 pounds in sequence by command as well as provision to cause valving to take place by command. The valve which was installed in the top of the balloon was a $10\frac{1}{2}$ inch diameter valve since previous indications were that the smaller valve was not adequate to cause lift to be lost rapidly at that altitude. The balloon was launched through a rain squall with a 10,000 foot broken ceiling and a 10 mile per hour variable wind. It was launched at the University of Minnesota airport, east section of the wind screen. The gross lift on the flight was 590 pounds with 55 pounds free lift and 690 pounds of air displaced. The initial rate of rise was 790 feet a minute and this increased in the usual way reaching a value of 1020 feet per minute between 100 mb and ceiling. On this flight the decision was made to not attempt to drop ballast or valve until the balloon had reached ceiling. Since the balloon broke at ceiling altitude, no test on the command system nor any flight constants were obtained in this operation.

Conclusions

This flight demonstrated that it is well to test out the radio gear during ascent since it is possible that the balloon may burst at ceiling. It also showed that the method of attachment of the horse tail appendix was inadequate since it is believed that the structural failure causing the balloon to burst probably occurred at the horse tail appendix.

FLIGHT #39

Flight #39 was launched on the 24 of September at 1325. It was a Winzen double-wall Air Force type balloon #2-100-V-86. It was equipped with a nylon cloth wrapped girdle, an 11 foot antenna and rubber padded corset. The tire which is inside the girdle was attached to the balloon by tapes to keep it from falling into the tied-off appendix. The purpose of flight was to test a different design of appendix which we called the duct-appendix. Although the tests for the horse tail appendix have not been very satisfactory, the factor which made us stop development on this appendix, was the fact that during certain periods of the flight the zero pressure level inside the balloon passes by the position at which the horse tail is attached. At these times the balloon would be able to take in air as was rather effectively demonstrated in flight #37. The new duct-appendix was based on the principle of attaching the appendix to the balloon at some point other than the bottom but some thought on this matter had demonstrated that the best place to attach the duct would be at the very top of the balloon. This would mean that as the balloon descends a positive pressure difference always exists on the appendix which positively keeps the air from flowing into the balloon. It also should be extremely effective in reducing diffusion into the balloon and if diffusion is the cause of the Howell effect, the duct appendix would also eliminate this undesirable behavior of balloons. In the actual installation of the duct on this flight it was attached approximately 20 feet down from the crown of the balloon, a point which is effectively at the top of the balloon. Further possible advantage of the duct is that it can be cut off at any length along the balloon thereby creating a sub-pressure balloon. Examination of the calculated balloon shapes for sub-pressure balloons indicated that cone-on-sphere balloons with a 60° cone angle could have the duct cut off at a point 40 feet up from the bottom

of the balloon without producing a serious volume defect. The duct was therefore run from near the top of the balloon to a point 40 feet up from the apex measured along the tapes. The standard appendix on the balloon was tied off. The duct was tied to the balloon with short lengths of nylon cord at various points along its length approximately 10 feet apart.

A further advantage of the duct appendix should be that since it sets the zero pressure level at some height up in the balloon the leakage below the bottom of the duct should be leakage of air into the balloon rather than helium and would therefore correspond to a very much smaller loss of lift. It's probably true that the region of the balloon below the bottom of the duct can be considered leak free in normal cases. In addition to this the pressure at the top of the balloon is reduced in the ratio of the two heights or the pressure is dropped to $2/3$ of its normal value and therefore the leakage of helium out through the top of the balloon is correspondingly less than it would be with a normal appendix at the bottom.

The flight was launched on a perfectly clear day in essentially zero wind conditions, a two mile per hour east wind. It was launched at the University of Minnesota airport in the southwest sector of the wind screen. The flight carried standard instrumentation with a beacon transmitter operating on 1746 kc. In addition to the usual instrumentation it carried receiver #10 which was added to allow the possibility of commanding several ballast drops. These ballast drops consisted of a 15 pound and a 25 pound ballast bag which could be blown by command. The balloon ascended normally until it reached 50,000 feet at which time it burst and descended. Examination of the up camera photographs after the flight showed that the

failure had occurred along the duct appendix at the point where it was attached to the balloon. These pictures showed us that it is impossible to attach such a duct without making sure in some way that the circumferential tension in the balloon is borne by some load carrying member. The duct on flight #39 had been attached simply by taping it on and reinforcing across with cross tapes which went across the opening under the duct appendix. After the failure of this flight to reach altitude we hit upon a better method of securing the duct appendix which was used in subsequent flights.

Conclusions

No actual flight information was obtained about the behavior of the duct appendix except that it behaved normally at low altitudes and could be seen to fill up on top with gas as one would expect and aside from the structural feature of fastening the duct appendix in, it seemed to introduce no difficulties in the launching or early stages of the flight. It was indicated by this flight that it is necessary to fasten the duct appendix in some way which definitely allows the circumferential and meridional stresses in the balloon to be carried by a load carrying member, certainly more effective than polyethylene or nylon taping.

FLIGHT #40

Flight #40 was launched on the 26 of September, 1952, at 1259. It was a Winzen double-wall Air Force type balloon. It was equipped with a nylon cloth girdle, which was attached to the balloon as in flight #39. There was a rubber padded corset and an 11 meter receiving antenna fastened into the balloon. The purpose of the flight was identical with that of flight #39, namely, to test the duct appendix. However, unlike 39, flight #40 had the duct appendix installed in a much more satisfactory way. The duct was inserted into the balloon at a point 13 feet down from the crown and was fastened in with aluminum clamping rings with screws in them. The duct extended down the side of the balloon ending 5 feet above the girdle or 44 feet from the very bottom of the balloon. Every 10 feet along the balloon it was attached by loops of string to the balloon. The standard bottom appendix on the balloon itself was tied off. As in flight #39 instrumentation was standard with 1746 kc telemetering and with the addition again of receiver #10 to allow command blow down of steel ballast shot bags. Again these ballast bags contained 15 and 25 pounds respectively of ballast. It was found during the flight, however, that because of low transmitter power (at the Control Station, a situation not previously recognized) the received signal in the balloon was too weak to operate these ballast bags when the balloon was near the line of sight range. Unfortunately for the radio tests it was not necessary to try to drop the ballast bags at short range. The flight was launched in the northeast sector of the University of Minnesota airport windscreen with a 4-8 mile per hour wind with clear weather conditions and no clouds. Its initial rate of rise was 445 feet a minute which increased to 476 feet per minute between 300 and

100 mb and it reached ceiling with a rate of rise of 750 feet per minute. After reaching ceiling the balloon valved properly through the improved duct appendix and the fact that the duct appendix allowed the balloon to operate in a sub-pressure way with some slack fabric was evidenced by the fact that the balloon oscillated with simple harmonic motion for seven cycles. The period of this simple harmonic motion was found to be five minutes. If one calculates the restoring force introduced by the adiabatic expansion and compression of the gas in the balloon, the value for the period that one would expect with only this restoring force and essentially no damping would be a period of five minutes in the stratosphere. The period would be correspondingly longer in the troposphere because of the difference in tropospheric lapse-rate. The oscillation at ceiling continued for approximately 40 minutes while the gas in the balloon warmed up. At the end of 40 minutes the flight continued level with absolutely no evidence of a Howell effect for a period of about 2 more hours before sunset occurred. At sunset the balloon established a rate of descent of 330 feet per minute which was maintained down to an altitude of approximately 70mb at which time the rate of descent began to decrease reaching a minimum value of 120 feet per minute at 125 mb. At 125 mb the rate of descent increased to 580 feet per minute and this altitude of 125 mb, incidentally, is exactly the altitude at which the tropopause was observed to lie on the day of this flight. Rate of descent of 580 feet per minute was maintained from the tropopause down to 300 mb at which point the chute release took place. The abnormally high rate of descent relative to average flights with open appendices indicates that the duct appendix is completely successful in keeping air from being taken into the balloon. Examination of the up pictures recovered after the flight showed that during the region in which the balloon could be observed in the up-pictures, that is before sunset, it descended prior to balloon sunset and contracted in

exactly the same way that it had expanded on its ascent. The up-pictures together with the observation of the constant rate of descent over quite a region of the stratosphere were taken to be quite convincing proof that the duct appendix was indeed successful in eliminating the intake of air for a descending balloon.

Conclusions

Flight #40 was one of the most significant flights of all that were made. One of the first things demonstrated was that the rate of rise of a balloon certainly does not need to be constant as a function of altitude. Because of the effectiveness of the duct no air was intaken at any altitude and the rate of rise characterizes a balloon which is filled with helium and expanding in a normal way without intaking air, mixing air or having to valve it out. It also demonstrated that the duct appendix operated in a manner that we expected from the theoretical analysis of natural shaped balloons. The period of oscillation of the balloon after reaching ceiling is in very good agreement with that calculated on the basis of adiabatic expansion and compression of the gas. The high rate of descent at sunset is significant of a balloon which did not take in air and was the first good measurement of sunset rate of descent on a balloon not contaminated with air. Level flight at ceiling after the oscillation was over indicated that the duct had also completely eliminated the so-called Howell effect.

FLIGHT #41

This flight was launched on October 2, 1952, at 1003 from the southeast sector of the University of Minnesota airport windscreen. The purpose of the flight was to measure flight constants by command valving and dropping of ballast. The balloon used was a Winzen double walled cell with a standard appendix which was tied off prior to launching. The balloon weighed 232 pounds and the gross load was 515 pounds. This was calculated to give a theoretical ceiling of 80,600 feet. In this balloon during packing, the tire which ordinarily slips down the balloon into the load ropes was taped with a length of tape to the side of the balloon so that after it was deflated and the girdle slipped off it would remain up on the balloon. Up-camera pictures showed that the tire did behave in a satisfactory manner and stayed up on the side of the balloon without any apparent damage. The gondola contained a command receiver, very similar to that used previously which operated a $10\frac{1}{2}$ inch diameter valve in the top of the balloon and also could drop a sequence of steel shot ballast in the sequence as follows: 10, 20, 30, 10, 20, 30 pounds. Command release could also be accomplished after all the ballast had been dropped. The standard Olland cycle telemetering on 1638 kc was used and this balloon was launched with a ground wind of 15 - 20 miles per hour with 5 to 10 thousand foot broken overcast. The balloon speeded up somewhat after release from 680 feet to 792 feet per minute. As the balloon passed the 70 mb level the valve was opened once by command and closed again. No perceptible change in the balloon velocity resulted from this and attempts were made to open the valve again but these were unsuccessful as apparently the noise from the valve motor blocked the command receiver. It became evident that the free lift could not be valved out

and that the balloon would burst at ceiling so it was decided to release all the ballast and command the load release before the balloon burst so that the parachute would open immediately rather than after a delay while the load fell to the 30,000 foot low altitude blow down point. The command ballast dropping proceeded and blow down took place. At this stage however the control operation was marginal and at first it was not realized that the ballast was completely off until the warbulator signal came through showing that the load had been cut loose. The gondola reached the ground in satisfactory condition despite the fact that several panels ripped from the chute. Both the load and the balloon were spotted down by the plane and were recovered complete.

Conclusions

Despite the fact that careful pre-flight check outs were made with the command system it was again demonstrated that the command link was too marginal to be safe. Accordingly following this flight a major effort was made to determine the difficulties with the command link. It was established again that the transmitter was generating a receiver image near the command receiver frequency of 6420 kc. It was also determined that the receiver did not have a narrow enough band pass in the RF section to attenuate this image and it was further determined that the signal strength of the command transmitter was inadequate to reliably override noise at the distances involved in command operations in the wintertime. The command type of flight was temporarily sidetracked while the necessary improvements were made in the command link, in favor of other measurements which had been on the program.

FLIGHT #42

This flight was launched on October 9, 1952, at 1251 and was made for the purpose of testing the new duct appendix, measuring the sunset effect on the balloon and measuring the effect of increment ballast drops on the ascent and descent of the flight. The balloon was a double-wall Winzen, 73 foot diameter, which was equipped with a standard appendix at the bottom, which, however, was tied off prior to launching. The duct appendix was installed the same as flight #40. The balloon weighed 232 pounds and with the gondola the gross load totaled 421# which gave a theoretical ceiling of 85,500 feet. This flight also carried cosmic ray plates weighing 5 pounds. The transmitter was on a frequency of 1746 kc and regular Olland cycle telemetering of pressure was included as well as high and low altitude barographs. The ballast control was set to drop 15 pounds as the balloon descended past 61,000 feet and 25 pounds when the balloon descended past 41,000 feet. The flight was launched in clear weather with a wind of 2-8 miles per hour southeast from the southwest sector of the University of Minnesota airport windscreen. In this flight an apparent error occurred in the weigh-off which is believed due to windlift on the inflated bag when it was in the horizontal position. The calculated free lift of 50 pounds does not correspond to the very low initial rise rate which was 350 feet per minute. The velocity of ascent increased from 350 between 980 and 500 mb to 512 between 500 and 300 mb and increased again between 300 and 100 to 575 feet per minute. The balloon reached the theoretical ceiling at 85,500 feet as measured by the Olland cycle with a slightly round corner and with no positive evidence of the height oscillations observed on flight 40. In this flight for the first time the launching was carried out entirely by one person following the weigh off of the gas in the horizontal position. The operation performed here included erecting the bubble lifting the gondola

from the ground, releasing the canopy and puncturing the diaphragm and setting the assembly into the air. There was no difficulty in carrying out this part of the operation with one person, which demonstrated that the rigging and launching were essentially in good shape. The balloon floated level at ceiling until sunset again demonstrating that the duct appendix eliminates the cause of the so-called Howell effect observed in balloons equipped with a standard appendix. The balloon began to decrease its altitude at 1720 and sunset occurred on the balloon at 1750 at which time it had established a rate of 430 feet per minute. This rate was maintained until the first ballast drop occurred at 70 mb when 15 pounds of shot were released. The balloon leveled for about 6 minutes following this ballast drop but then established a new rate of descent of 94 feet per minute which was maintained until the second ballast level was reached at 150 mbs. At this point 25 pounds of ballast were dropped and the balloon established an upward rate of between 800 - 1000 feet per minute which persisted for about 4 minutes during which time the velocity decreased and a new rate of climb was established which persisted for several hours with a rate of 160 feet per minute. The initial rate from 2050 to about 2320 was 160 feet per minute. The balloon then gradually slowed down but continued to rise and then leveled at 0340 the next day until sunrise at which time the balloon climbed again to ceiling. The balloon floated practically level throughout the day and at sunset had established a rate of 372 feet per minute which it maintained until the low altitude release operated at 300 mb. The load was on the ground at 1948 on October 10. The time altitude curve contains data not only from the Olland cycle radio telemetering but also from the high altitude, low altitude barographs. The high altitude barograph gives a consistently lower pressure during the first day than the radio telemetered Olland cycle. This high altitude record is not

reliable at pressures above 70 mb but is considered to be reliable at pressures lower than this. On the second day the Olland cycle and high altitude barographs are in much better agreement but at that time the Olland cycle gives a lower pressure reading than it did on the first day which is difficult to understand in terms of any balloon behavior. Furthermore on the first day the theoretical ceiling corresponds exactly to the value given by the Olland cycle. One must conclude that there was some small change in the calibration of the Olland cycle during flight although it was checked after return of equipment and agreed very well with calibrations made just before the flight. A number of interesting characteristics of balloon flight are revealed by this time altitude curve - first, that the sunset effect corresponds to a velocity of 430 feet per minute and that it should be noticed that when the first 15 pound ballast drop occurred the balloon bobbed for a few minutes nearly level and then established a new rate downward. This is probably evidence for the adiabatic cooling of the gas as the balloon began its initial rise after the ballast drop. This cooling is evidently connected with the fact that the balloon gas during the descent is warmer than the outside air and that when the descent is stopped by release of ballast the gas cools and the loss of lift brings about a new equilibrium condition represented by a new downward velocity. While the gas is cooling the balloon remains in static equilibrium for a few minutes. When the second ballast drop of 25 pounds at 150 mb occurred the balloon rose at a relatively high rate and then slowed down very quickly to the equilibrium rate. This rounding off evidently shows the rapid adiabatic cooling of the balloon gas with a corresponding loss of free lift. If one assumes that the process is adiabatic between 152 and 135 mb one finds that the balloon temperature drops 11.6 degrees. Furthermore, it is to be noted

that the rate of ascent after this ballast drop was closely the same as the rate of descent before. One can find the sunset loss of lift in terms of ballast by adding to the initial 15 pounds one-half of the 25 pounds, giving a sunset ballast of $27\frac{1}{2}$ pounds which corresponds to 6% of the air displaced by the balloon floating at ceiling just before sunset. The relation of the changes in velocity to the ballast drop permit this flight to be used to evaluate the flight constants. Data from this flight along with other flights will be tabulated and discussed in another section of this report.

Conclusions

The duct appendix besides producing level flight at ceiling at the theoretical altitude insures that the balloon will return to its theoretical ceiling the second day without intake of air despite having descended to a rather low altitude during the night. The flight demonstrates a rate of rise that is not constant and clearly shows the effects of adiabatic cooling and heating on balloon flight behavior. The duct also insures that the balloon will positively descend to the ground after sunset after ballast is exhausted.

FLIGHT #43

This flight was launched October 14, 1952, at 1322. The balloon was a double-wall Winzen equipped with a duct appendix installed with aluminum clamp ring down from the top at about 14 feet. A nylon cloth girdle and corset padded with rubber which at this point is standard procedure was used. The purpose of the flight was to find the sunset effect on a balloon inflated with helium and needled ammonia using the new duct appendix to definitely exclude air from the balloon on descent. The gross load of 375 pounds corresponds to a theoretical altitude of 86,500 feet. A relatively simple gondola was used containing a transmitter on 1638 kc, Olland cycle, up and down cameras and a small package of cosmic ray plates. The inflation contained 70 pounds of helium and approximately 25 pounds of ammonia and the balloon was launched from the south east sector of the University of Minnesota Airport windscreen with a west wind of 10-12 knots and a broken cloud cover. The balloon rose at an almost constant rate of 686 feet per minute to an altitude a little higher according to the Olland cycle than its theoretical ceiling. It maintained this altitude with a very slight decrease from 1510 to 1700 and established a descent rate after sunset of 444 feet per minute. Between 100 and 300 milibars the average rate was 330 feet per minute. The balloon reached 300 milibars at 1940 and the load cut loose and reached the ground at 1953. The overall average rate between 30 and 300 milibars was 382 feet per minute. This flight like flight #40 showed a series of oscillations immediately after reaching ceiling. The descent rate is very similar to that obtained on this type of balloon with pure helium inflation and apparently the particular fraction of ammonia used had no effect on the balloon's stability after sunset. The balloon was above an overcast throughout the flight.

Conclusions

This flight does not resemble previous flights containing part ammonia inflation in that it did not accelerate during ascent and showed a sunset effect much the same as for the helium. This flight, however, definitely had the air excluded by the duct appendix, therefore may not be comparable at least on descent.

FLIGHT #44

This flight was launched October 16, 1952, at 1305 for the purpose of testing the duct appendix and sunset effect on a one and a half mil balloon made without tapes. The balloon was of Winzen manufacture and was a standard 73 foot diameter cell with the load suspended by a tape harness near the bottom of the balloon and with another tape harness near the top of the balloon to support the crown. The gondola was set for a 48 hour flight and was equipped with a 15 pound ballast drop to release at 58,500 feet and a 25 pound drop at 39,000 feet. The radio frequency was 1638 kc and besides the balloon equipment the flight carried a paraffin and lead block cosmic ray experiment which weighed about 60 pounds which was put on this flight because it was desired to make the gross load approximately equal to a taped balloon. With a gross load of 389 pounds the theoretical ceiling was 87,000 feet. This balloon weighed 148 pounds. The balloon was launched without difficulty from the southeast sector of the University of Minnesotawindscreen in a calm with heavy overcast and a ground temperature of 20°F. The balloon rose at 704 feet per minute to 26,000 feet where the balloon failed and the load was put on the parachute by the low altitude descent release. Both the balloon and the gondola were recovered in good condition. The balloon was examined and the cause of failure was determined to be weak heat seals. One could go along a seal stretching it transversely by hand and find a good bond for quite a few feet but suddenly a weak spot would appear in which this seal would come apart with scarcely any force. This was repeated at many places on the balloon. A conference was held with the manufacturer and according to him the trouble was that the plastic material was spotty and in places was poor and could not be heat sealed successfully.

Conclusions

The only things learned were that the tapeless balloon could be packed and launched without difficulty. The sunset effect was not measured because of the material failure.

FLIGHT #45

This flight was launched October 20, 1952, at 1310 and used a Winzen one-mil balloon equipped with a duct appendix installed 14 feet down from the top set in with an aluminum clamp ring. The balloon was made with one inch glass filament tapes. The purpose of the flight was to measure the sunset effect with the duct to exclude air on a one-mil balloon. The gondola was set for 40 hours duration with a 1638 kc Olland cycle transmitting beacon and two ballast droppers, the first set to release 15 pounds when the balloon crossed 60,000 feet on the way down and the second one set to release 25 pounds at 40,500 feet. This balloon was launched from the University of Minnesota Airport in a northeast sector of the windscreen with the wind from 8 to 10 knots southwest, clear skies with cirrus beginning to form. Fifteen pounds of added weight were put on the flight to reduce the free lift after a slight over-inflation. The gross load was 393 pounds and the balloon rose with an almost constant rate of 752 feet per minute until just before theoretical ceiling where it rounded off and began to descend. The velocity of descent increased and the load came all the way back down to the ground with impact about 1625. The load and balloon were recovered at New Albin and Lewiston, Minnesota, respectively and an examination of the balloon upon recovery showed a hole or rip along the tape near the appendix installation point about 14 feet down from the top of the balloon. The material bordering the hole was degraded from flutter, that is, having a noticeable milky appearance showing that the rip valved gas. All the free lift was valved by the time the balloon reached an altitude slightly below theoretical ceiling. It seems that the installation of the duct with the aluminum clamp ring had stressed the material unfavorably and because of its light weight, that is, being only one-mil thick had produced the hole which caused the failure of the

flight. This flight like the three before it was launched by one person alone after the final horizontal weigh-off had been completed.

Conclusions

This balloon failure indicated that more care would have to be taken with the installation of the duct to avoid stressing the balloon unfavorably. Before this time consideration had been given to installing the duct in the center of the top of the balloon and it was anticipated that this would be carried out on subsequent operations and accordingly no great thought was given to the problem of reinforcing the balloon at the point where the duct was installed down from the top.

FLIGHT #46

This flight was the first to be launched from the winter site at the Pierre Municipal Airport, Pierre, South Dakota. The facilities there had been investigated and a large square hangar provided sufficient wind shelter for the launching operations. At the time of this launching the semi-trailer had the final modifications completed and was driven out to Pierre and put into operation. It was decided to set off a series of three flights in one trip, of which the present one is the first. The purpose of this flight was to measure the sunset and ballast effects on a one-mil balloon equipped with a duct appendix. The balloon used was a Winzen one-mil cell with a duct appendix installed in the top and terminated 8 feet above the girdle. A taped girdle was used which would predict that the girdle would drop at a fairly low altitude, approximately 15,000 feet. The balloon was launched November 3, 1952, at 1150. The gondola contained an Olland cycle transmitter on 1746 kc, up and down cameras and the usual standard equipment. A 68 pound cosmic ray plate pack and a recorder to record the reading of two different thermistors, one measuring the outside air temperature and the other the temperature of the balloon's skin. Last minute difficulties with the attachment of the balloon skin thermistor made it seem advisable to leave it and only the external air thermistor was carried. The thermistor record was obtained with an automatic recording camera which photographed a meter. The flight was launched from the apron in front of the hangar with a 20 mile per hour southwest wind which created strong gusts and burbles over the top of the hangar. The turbulence caused some difficulty with the launching which had to be carried a short distance along the apron before it took to the air. Clouds were scattered and of

cirrus or altocumulus type. The balloon rose with a velocity between 300 and 100 milibars at 540 feet per minute but it became evident that the balloon was slowing down and it reached a ceiling of 82,900 feet, well below the expected theoretical ceiling and then began to descend. The balloon had dropped to 80 milibars when sunset occurred. About 20 minutes before this the balloon crossed the high altitude ballast point and released 10 pounds of ballast. There was a noticeable change in rate of descent from 276 to 164 feet per minute. Then at sunset the velocity increased from 164 to 600 feet per minute which carried the balloon to the second ballast level at 165 milibars where 25 pounds of ballast was released and the rate dropped from 600 to 148. The balloon then began to enter the troposphere and the rate gradually increased again up to 550 feet per minute when the load was released at 300 milibars. The equipment was on the ground at 1914. The flight is characteristic of a balloon with a sizable leak estimated at about one square inch size which would result in a loss of lift of 60% of the gross load per day. On this flight a good temperature record of the outside air was obtained with a thermister and in addition a manometer contained in the temperature measuring system was plotted up and is given on the time altitude curve along with the Olland cycle record. Despite the fact that the balloon leaked the changes of velocity corresponding to ballast drops give significant information.

Conclusions

The cause of the opening of the hole in the balloon is not determined as the launching seemed to have been very good. The ballast drops give values significant in determining flight constants and the change in velocity in going through the tropopause agrees with the measured change in lapse rate from meteorological soundings and the temperature data ob-

tained on the flight. The failure of the balloon supports other conclusions from one-mil flights that one-mil balloons have a relatively high failure probability compared to balloons of thicker material, for example double-wall material.

FLIGHT #47

Flight #47 was the second flight of the first group of three launched from the Pierre Municipal Airport at the Northeast side of the hangar, that is, the front side. The flight was made for the purpose of measuring sunset and ballast effects on a one mil balloon with the new duct appendix and was launched November 4, 1952, at 1436. The balloon had the duct installed 14 feet from the top and was terminated five feet above the girdle or about 48 feet from the bottom of the balloon. The balloon was a one mil Winzen cell weighing 161 pounds. The flight was set for a 48 hour duration in anticipation that the ballast drops were set to be 25 pounds at 60,000 feet and another 25 pounds at 40,400 feet and would be sufficient to keep the balloon up two nights. A standard gondola was used which included a cosmic ray pack and the inflation was pure helium. The balloon was launched in a 15 mile per hour southwest wind with some broken cirrus clouds. The wind burble over the top of the hangar made it necessary to hand launch the load somewhat like flight #46. The balloon had an almost constant ascent rate of 800 feet per minute and reached ceiling at 1630 with a slightly rounded time altitude characteristic. The balloon floated very level until 1740 and then established a rate of descent of 250 feet per minute following sunset. The balloon was not noticed to have responded to the ballast drops and continued its downward motion at a nearly constant rate until it reached the tropopause where it dropped off more rapidly to 300 mb at which point the load was cut loose. Examination of the gear on recovery showed that the ballast had not been dropped and that there was a malfunction in the pressure ballast switch of undetermined origin. This flight demonstrated a very good flight characteristic for a one mil balloon and apparently was gas-tight. The sunset

effect calculated from this is substantially lower than that obtained with 2 mil balloons. The sunset loss of lift corresponding to the downward velocity of 250 feet per minute is 4% as contrasted with a value of 6% obtained from a 2 mil balloon with the same type of tapes.

Conclusions

Despite the failure of the ballast drops which would have yielded valuable flight constant data the flight gave the principal result which was to measure the sunset effect on a one mil balloon and gave another point on the curve in the determination of sunset effect vs. balloon thickness, number of tapes, etc. The determinations were made on the basis of using the duct appendix to exclude the effect of air on the downward motion of the balloon.

FLIGHT #48

This flight was launched November 6, 1952, at 0802 and the purpose of the experiment was to test a ballonnet combined with a duct appendix. The ballonnet was designed to permit air to enter the bottom of the balloon but not to mix with the helium. In this way as the balloon descended it could take air and become stable but would be able to rise again the next morning at sunrise and expel the air and gain back its initial ceiling. The duct appendix would insure that air was not intaken through the appendix and that the balloon could valve and level off when it reached ceiling initially. The balloon used was a Winzen 1-mil, #73-100-V-171. The ballonnet was formed by taking the conical portion of balloon #150-V-147 which had been flown previously and taping this conical portion directly over the conical portion of the main balloon. The tape joint was made as tight as possible and was made strong enough to support the load on the outer taped on cone. The inner cone, which was a part of the main balloon, was secured to a wooden inflation thimble at the bottom with a polyethylene inflation hose so that the helium could be fed in in the normal manner. The net weight of the balloon was 224 pounds. The flight was planned for 48 hours so that it would go through two sunsets and carried gondola no. 16 which contained standard instrumentation plus a ballast dropper set to drop 25 pounds of ballast at 60,100 feet and 25 pounds more at 41,300 feet. The gondola also contained a command type radio receiver with a photo recording ammeter to measure the AVC voltage at high altitude to assist in perfecting the control valving and ballast flight constants experiment.

The balloon was launched from Pierre, South Dakota, Municipal Airport on the southeast side of the hangar with a wind of 11 miles per hour NNW. The flight was in the air 22 minutes but began to descend and was cut down by the

low-altitude ratchet release. The load dropped to the ground on a parachute. There was a large leak in the top of the balloon which caused the failure. The balloon came down about 15 miles from the launching site and the transmitter stayed on the air and gave the signal most of the day but there was difficulty in locating the gondola. When it was discovered it was found to have landed in such a fashion that the antenna was supported off the ground for its entire length. It was recovered in good condition.

Conclusions

There are no conclusions regarding the performance of the ballonnet in stabilizing the balloon but the type of construction used on this very preliminary model appeared not to be satisfactory. The use of the 1-mil balloon is probably inadvisable due to its lower strength.

FLIGHT #49

Flight #49 was launched November 20, 1952, at 1654 from the Pierre Municipal Airport, in front of the hangar. This balloon was a Winzen #73-150-D-208 with a duct appendix down to the girdle position. This was a $1\frac{1}{2}$ -mil balloon. The purpose of the flight was to measure the effect on the rate of climb of sunset and to measure the climb rate at night through the tropopause as it had previously been observed that balloons on the ascent showed little or no change of velocity when passing the tropopause whereas on the way down, large effects are observed. The flight duration was set for 48 hours. The balloon remained in the air for a little over 1 hour. It carried gondola no. 16 and besides standard equipment contained a sequence ballast dropper which dropped 15 pounds at 50 mb and 25 pounds at 172 mb. The balloon was manufactured with filament tapes and weighed 222 pounds complete. The balloon was weighed off to 65 pounds of free lift with a gross load of 391 pounds and 521 pounds of displaced air. This put the free lift at 12% of the air displaced and accordingly the balloon had a rather high rise rate which was initially 1000 feet per minute. The balloon climbed at essentially a constant rate of rise of 1000 feet per minute through sunset through the tropopause. The balloon then failed and the load was dropped on the parachute. It was recovered $3\frac{1}{2}$ miles west of Gann Valley, South Dakota, in the open prairie. The failure of this balloon was almost certainly due to the same causes as the failure of the sister balloon also made by Winzen which was used on the tapeless balloon test.

It was found on this former balloon that the heat seals were very poor and it was assumed that the same condition existed on flight #49. Winzen attributed this to poorer quality of polyethylene and was skeptical of this balloon. The night condition and fast rate of rise imposed a severe temperature condition.

Conclusions

At this rate of rise the change in superheat due to sunset and the change in thermodynamic drag due to lapse rate difference between troposphere and stratosphere produced no detectable changes in velocity. However, the velocity is quite high and it would be desirable to examine this effect with a lower velocity where the aerodynamic drage would be of less importance.

FLIGHT #50

Flight #50 was launched November 22, 1952, at 1129 from Pierre Municipal Airport from the apron in front of the hangar. The balloon was a GMI type 734J-254 #492 with a duct appendix to the girdle and constructed of 2-mil polyethylene. It weighed 329 pounds which corresponded to a theoretical ceiling of 81,000 feet. The purpose of the experiment was to measure the sunset effect on a 2-mil balloon with double the usual number of tapes to help in determining the causes of the sunset super heat, that is, to separate the effect of the tapes and the plastic. The flight was set up for 48 hours and contained gondola no. 15 with standard equipment plus a sequence ballast dropper to drop 25 pounds at 50.5 mb, 25 pounds at 160 mb. The balloon was launched in cloudy weather with 11,000 feet scattered and 18,000 foot high thin overcast. Due to the fact that the bottom cover of the gondola was not removed prior to launching the balloon went into the air with the cover on and accordingly the antenna did not drop out so no telemetering signal was obtained. However, a time-altitude record was obtained from the down-camera which recorded the Olland Cycle signal. Due to fluctuations in the speed of the camera an oscillation was super-imposed which was ascertained not to be characteristic of the balloon. The ballast droppers operated but about 12 pounds of ballast shot was caught in the bottom cover as the ballast bag was directly over it on one side. The total amount of ballast dropped was 38 pounds and was not sufficient to compensate for the sunset effect. Accordingly the balloon reached the low altitude release at 1920 and the load came down on a parachute. The gondola was recovered 8 miles north of Manongo, North Dakota.

Conclusions

The balloon had a larger sunset effect than similar balloons with one set of tapes and the extra set of tapes contributes an appreciable amount of super-heat. The launching bubble was filled to what was considered a safe upper limit of inflation for this balloon, which on the present flight was 630 pounds of displaced air. This balloon was approximately 12 feet shorter in gore length than the 73' cone-on-sphere shape balloons usually flown. It has the natural shape or at least an approximation of the natural shape on top and then a more or less conical shape at the bottom.

FLIGHT #51

Flight #51 was launched the 24 of November, 1952, at 0821. The balloon was a GMI type 733-EH #457, was 2-mil thick and made with no. 880 tapes, was equipped with a duct appendix down to the girdle and a valve for flight constants experiments. The balloon weighed 278 pounds and the purpose of the flight was to measure flight constants on a 2-mil balloon with a planned duration of 48 hours. The gondola was no. 20 which contained the standard equipment plus the command receiver and control unit #9 and sequence ballast dropper which was arranged to drop 10-20-30, 10-20-30 pounds of ballast in that order by means of a stepping relay. The valve was operated by radio control also using one of the resonant relay frequencies, the other one being reserved for the stepping relay for the ballast dropper. The gross load was 542 pounds and 64 pounds of free lift were provided so that the percentage free lift in terms of displaced air was 9.2 which gave an initial rate of rise of 630 feet per minute. The balloon was launched from the Pierre, South Dakota, Airport with a ground wind west 3 miles per hour and about 5/10 cloud cover at 12,000 feet. The balloon rose to about 600 mb and than began to descend and the load was cut loose by the low-altitude ratchet release and came to the ground 7.1 miles east of the launching site. On this flight we apparently have a balloon failure that occurred rather suddenly as the balloon rise rate was constant up to 600 mb and the descent began rather suddenly. The kind of hole that opened in the balloon is not known as the balloon was not recovered in a form suitable for examination. There are no conclusions regarding the main purpose of the experiment which is to measure flight constants by radio control.

FLIGHT #52

Flight #52 was launched December 6, 1952, at 1943 from the Pierre Municipal Airport. The balloon flown was a Winzen double-wall 1-mil balloon #73-2-100-V-245 with a duct appendix terminated 3' above the girdle and with a total weight of 273 pounds. Its theoretical ceiling was 86,500 feet and a 44 hour flight was planned. The purpose of the flight was to determine the rate of rise through stratosphere at night to see if any noticeable changes in velocity occur at the tropopause. The gondola, no. 53, besides standard equipment contained a sequence ballast dropper arranged to drop 15 pounds at 50 mb on the way down and 25 pounds at 158 mb. The gross load was 390 pounds and the flight was weighed off to a free lift of 27 pounds which is 5.6% of the displaced air. This produced a rate of rise of 455 feet per minute which was essentially constant up to an altitude of 67,000 feet at which time the velocity rapidly decreased and at 70,000 feet the balloon began to descend rapidly and eventually the load was cut loose. All of the gear and the balloon was recovered at Clark, South Dakota, in a somewhat damaged condition. This flight had a rather light load and was initially over-inflated. Some helium was then removed from the balloon by using the intake manifold of a truck engine until the correct free lift was obtained. The balloon was believed to be a good balloon and the source of failure is not known although the low night temperatures in climb may have produced an effect.

There was no break noticed at the tropopause.

Conclusions

Even moderate rates of climb at night do not show a break at the tropopause although on a descent this is repeatedly observed to produce a speeding-up as the balloon lowers into the troposphere. Apparently this flight also shows some weakness in the balloon when subjected to the colder conditions at night which produced this particular failure.

FLIGHT #53

Flight #53 was launched December 7, 1952, at 1213. This flight was for the purpose of measuring the sunset super heat on a double tape 2-mil balloon for evaluating the effect of materials as applied to the balloon in increasing the sunset super heat and consequent rate of descent. The balloon was a GMI type 734-EH #491 2-mil thick and weighing 330 pounds. This balloon was equipped with double the ordinary number of tapes for supporting very heavy loads. The duct appendix was used down to the girdle and the flight was set up for 48 hours. Gondola no. 54 contained besides the standard equipment a sequence ballast dropper which on the descent would drop 45 pounds at 51 mb and 15 pounds at 167 mb. The gross load was 470 pounds and the flight was provided with 30 pounds of free lift which is 4.95% of the air displaced. The balloon was launched from the Pierre, South Dakota, Airport with a south wind of 5 miles per hour and a high overcast. The flight gave a very satisfactory performance; it climbed at 420 feet per minute initially and slowed down at 250 mb to 350 feet per minute, continued at this rate until it reached theoretical ceiling which was 30 mb or 79,000 feet. The balloon then leveled, becoming first level at 1520 and at 1635 it began the sunset rate of descent and increased to 485 feet per minute. It was descending at this rate when it passed the first ballast point and the ballast dropped at 52 mb. The balloon then bounced upward and leveled again at 41.5 mb and continued in this level flight. It was obvious that the 45 pounds of ballast dropped at this point exactly compensated the sunset effect which gave a very precise value as a result.

The height of the bounce gave an adiabatic cooling temperature of 17.4°C and if one takes the fractional temperature compared to the temperature of the balloon at ceiling from the bounce one gets an 8.1% sunset super heat and from

a ballast of 45 pounds one gets a 9% super heat due to the sunlight. This is considered to be a very good agreement as there is some effect due to the aerodynamic drag which reduces the downward velocity and consequently reduces the temperature change when the balloon stops moving. This balloon continued level until 2140 at which time it descended with velocity of 100 feet per minute until 2310 at which time it leveled again and continued practically level at 70 mb until sunrise when it established a rate of 530 feet per minute and went back to the new theoretical ceiling, at least within one or two mb, at 81,300 feet. The balloon then floated level until the signal was lost at 1030 the next day, December 8. The balloon and load as of the present date of writing have not been recovered.

Conclusions

This flight gave a very good value for the sunset superheat on the double taped balloon and it is very definitely higher than observed with single tape balloons which give the order of 6% to 7% whereas 9% is observed here. It is very clear that the extra set of tapes introduce a large additional superheat. The flight also shows the effects of earth radiation changes during the night as the balloon descended and leveled again which could only mean that the balloon cooled somewhat and rewarmd again to its original temperature at a slightly lower level. Such slow changes of altitude during the night have been observed repeatedly on flights which are caused to level below theoretical ceiling so that they may move either up or down without loss of gas. It is regrettable that the signal was lost the second day but this behavior could be predicted from the radio forecasts which show that balloons which take a northeasterly trajectory get into the auroral zone where radio transmission on this frequency is rather poor.

FLIGHT #54

Flight #54 was prepared for the launching time of 1220, December 9, 1952, from the Pierre, South Dakota, Municipal Airport. The flight utilized a Winzen double-wall balloon #346 with a duct appendix cut three feet above the girdle with a weight of 294 pounds. The purpose of the flight was to measure flight constants with radio control of ballast in valving and the flight was set up for 48 hours. The sequence ballast dropper was arranged to drop increments of 10-20-30, 10-20-30 pounds in that order. The gondola was no. 14 and contained the customary radio control equipment, command receiver, distribution box, balloon valve control batteries and relays etc. The gross load was 546 pounds. This flight was not successful due to a launching failure. Gas started to transfer into the upper part of the balloon prematurely through a leak either in the diaphragm or around it. After the balloon was erected and the corset removed there was enough lift into the top to carry the canopy upwards and it caught in the wind and was blown downwind into some telephone poles and lines. The gondola did not leave the launcher's hands but the balloon was destroyed. The failure was possibly due to a deflated tire or partially deflated tire as the tube deflator element was set closer than normal due to a mistake in judgement on the part of the launching crew.

FLIGHT #55

Flight #55 (also Winzen flight #118) was launched December 21, 1952, at 1254. The purpose of this flight was to measure aerodynamic and thermodynamic balloon constants and sun effect with a known mixture of air and helium in the balloon. The balloon was a Winzen double-wall 1-mil with a duct appendix no. 254 and it weighed 244 pounds. The launching was a platform launching performed by Winzen Research due to the fact that a large amount of gas could not be inserted into a bubble using the Minnesota method on this size balloon. The air and helium were fed into the balloon by a blower, actually the same one used for the Weeksville Hangar Inflations and the calibrated manometer was set up to give a 50:50 mixture of air and helium. As far as could be determined the mixing was very good and the bubble with a 51' gore length was quite full. Inflation took about 1 hour and was carried out at the old University of Minnesota wind-screen using the GMI motor generator set to provide power for the blower. The launching was smooth and the balloon had an initial rate of about 230 feet per minute. The gross load was 394 pounds and the free lift calculated from bottle pressures was 79 pounds which is 20% of the gross load but only 7.1% of the displaced air which was 1,110 pounds. The flight was launched in a 4 mile per hour northeast wind and a heavy fog of from 500 to 2000 feet and a 12,000 foot overcast above. The temperature was 20° and frost was forming at the time. Following the initial rate of rise of about 230 feet per minute at 600 mb the rate increased to 470 feet per minute and continued constant to 230 mb where it dropped to 222 feet per minute. At 110 mb it again increased somewhat and the balloon began to level at 1650. The theoretical ceiling was 41 mb but the balloon leveled at 54 mb because of the fact that sunset occurred at that time and apparently the free lift was just compensated by the sunset. The balloon leveled and continued through the night with some very slow rates of descent and ascent. At 0750 the following morning

the balloon rose to its theoretical ceiling and shortly thereafter the signal was lost.

Conclusions

This was the first flight to show a large effect at the tropopause on the ascent and it is assumed that because of the large air content that the difference in lapse rates produces a much more pronounced effect on the thermodynamic drag than in a pure helium flight. The sharp change in velocity at 230 mb from 470 to 222 feet per minute occurred exactly at the tropopause as given by weather station soundings in the vicinity of Pierre. Although the free lift of the balloon at the time of sunset was exactly equal to the sunset effect, one cannot associate this with the free lift on the ground due to possible changes in super heat as the balloon rises due to earth radiation and also because of the questionable accuracy of the weigh-off as it was computed using volume of tanks and temperature of helium in the helium trailer instead of a direct weigh-off as is usually the case.

FLIGHT NUMBER	21	22	23	24	25	26	27
FLIGHT DATA							
Date Flown	June 25, 1952	June 30, 1952	July 3, 1952	July 8, 1952	July 15, 1952	July 21, 1952	July 23, 1952
Time	1100150	1515	1333	1045	1045	144915	1537
Balloon Type	No. 18 General Mills 1161 A-3235	Wissen 72.8 feet x 1.5 mil Destruction tape. Glass fila- ment. Short appendix. Polished girdle. 11 M. antenna.	No. 19 General Mills 1161 - A 3273 Glass filament tapes Short appendix Taped girdle 11 M. antenna	Wissen 72.8 feet x 2 x 1 mil Glass filament tapes 8-foot. appendix From rubber between core and girdle. 11 M. antenna	Wissen 72.8 ft. x 1.5 mil Glass filament tapes 8-foot. appendix From rubber between core and girdle. 11 M. antenna	Wissen #2(100-V-122) double-wall 1 mil. Glass filament tapes Leather reinforced core, taped aluminum girdle, new model appendix (has four breather holes), 11-M. antenna	Wissen double-wall - 1 mil. #2(100-V-127) Glass filament tapes, taped aluminum girdle, 11 M. antenna, core.
Date Packed and Packed	June 24, 1952 Hanson, Lahti, Wase	May 7 - initial packing Hanson, Edwards, Smith June 9 - Helium thistle added June 30 - 10-diameter hole put in top of balloon	July 1, 1952 Hanson, Edwards, Lahti, Smith	June 20, 1952 Smith, Lahti, Edwards	July 9, 1952 Smith, Edwards, Lahti	July 16, 1952 Smith, Edwards, Lahti	July 15, 1952 Hanson, Edwards, Smith
Balloon Weight	261 lb.	177 lbs.	247	227	180	234	222
Altitude Theoretical Maximum	94,500 feet 47,600 feet	83,000 5,932	106,500	83,000 feet 83,000	80,500 11,192	83,000 35,000	83,000 83,000
Purpose	Ammonia duration and rate of rise Launch of 3/4 million with ammonia	Flight constants Command system	Sunset effect and flight characteristics of 116 ft. cell	Ballast drop Dilute ammonia experiment Double-wall behavior	Command ballast, command blow-down, flight constants, appendix closing.	Command ballast, command blowdown, needed ammonia, octopus appendix.	Command ballast, command blow- down, needed ammonia, octopus appendix.
Duration Planned	24 hr.	22 hrs.	22 hrs.	22 hrs.	22 hrs.	18 hrs.	Approx. 50 hrs.
Actual Duration	1 hr. 17 min.	10 min.		21 hrs. 30 min.	1 hr. 6 min.	10 minutes	33 hrs. 13 min.
How Released	Balloon broke in jet stream	Balloon settled to ground.		Timers	Radio command blow-down	Balloon burst	Balloon and load settled to ground.
CONDOLA DATA							
Condola No.	5	7	6	6	7	11	2
Radio Bear	1638 Kc. transmitter #21 Modified Olland cycle #5 Vibrapack #7	1746 Kc. XMR #24 6420 ROVR #7x Mass Vibrapack #2 Olland cycle #7 132 Mc. #321	1746 Kc. XMR #11 Olland cycle #11 Bellsows Vibrapack #8 6420 Receiver #5 133 Mc. #121	1746 Kc. XMR #11 Olland cycle #11 Bellsows Vibrapack #8 6420 Receiver #5 VHF Receiver-121-133 Mc.	1746 Kc. XMR #60 Olland cycle #15 6420 Kc. Receiver #7x 210-cycle radio-controlled blow-down #11. Vibrapack #11 6420 Receiver #7x 133 Mc. XMR #2	1746 Kc. XMR #60 Olland cycle #15 6420 Kc. Receiver #7x 210-cycle radio-controlled blow-down #11. Vibrapack #11 6420 Receiver #7x 133 Mc. XMR #2	1746 Kc. XMR #60 Olland cycle #15 6420 Kc. Receiver #7x 210-cycle radio-controlled blow-down. 234-cycle radio-controlled ballast.
Blow Down	Blowdown box #3 Cocks 18,000 feet Fires 30,000	Blowdown box #2 Cocks 18,000 feet Fires 30,000	Blowdown box #4 Cocks 12,000 feet Fires 31,000	Blowdown box #1 Cocks 12,000 feet Fires 31,000	Blowdown box #2 Cocks 10,800 Fires 31,200	Blowdown box and low-voltage blowdown #20 Cocks - 19,000 ft. Low voltage hold - 5.0 V. fire - 4.0 V.	Blowdown box and low-voltage blowdown #21 Cocks - 50,000 Fires - 30,500 Low blowdown holds at 5.0 V. fires at 4.0 V.
Cameras	Up #16 Down #14	Up #15 Down #2	Up #18 Down #17 Horizon #19	Up #18 Down #17 Horizon #19	Up #15 Down #20 Crown #16 Mount #3	Up #18 Down #2 Out #19 Ballon camera #13 (starts at 3,000 ft.) Ballon camera mount #2	Up #15 Down #17 Out #21
Ballast	None	100 lbs. fine steel shot Ballast level XMR #3 Ballast tank #2 Magnetic ballast valve #1	60 lbs. fine steel shot (4 - 15 lb. bags) Ballast distribution box #11	30 lb. fine steel shot Ballast level recorder #3 Ballast tank #2 Magnetic valve #2	100 lbs. fine steel shot Ballast level recorder #3 Ballast tank #2 Magnetic valve #2	30-lb. lead box containing cosmic ray plates. Ballast and blow- down distribution box #11.	30-lb. lead box containing cosmic ray plates. Ballast blowdown distribution box #11.
Cosmic Ray	None	2 x 1/2 plates 1/2 x 8" standard pack	1/2 x 8" plates (G. Anderson) Plates (Shapiro) Cosmic ray blowdown timer #1 Cocks 53,000 feet Fires 38,000	1/2 x 8" plates Plates (Shapiro) Cosmic ray blowdown timer #1 Cocks 53,000 feet Fires 38,000	2" x 1/2 cosmic ray plates 1/2 x 8" cosmic ray plates (standard pack) 2" x 1/2 plates (enclosed in 30-lb. lead block)	Same as above plus standard pack (1/2 x 8" plates) in C.R. plate box #1.	Same as above plus C.R. plate box #2.
Light	Blinker beacon #5	Blinker beacon #6	Blinker beacon #5	Blinker beacon #5	Blinker beacon #6 Appendix closer #10-1	Blinker beacon #7	Blinker beacon #7
Barograph	Baro-thermograph #7	Baro-thermograph #8	Baro-thermograph #9	Baro-thermograph #9	Baro-thermograph #10	Baro-thermograph #11	Baro-thermograph #12
Miscellaneous	Timers #9 and #10 Batteries #29, #30, #31	Timers #2 and #6 Batteries #26, #27, #28	Timers #11 and #12 Batteries #33, #34, #35	Timers #11 and #12 Batteries #33, #34, #35 Standard appendix	Timers - #13 and #14 Battery - #39	Battery #37 New model octopus appendix Apex tiedown cord appeared to have fouled in apex ring, not allowing complete erection.	Battery #38 New model octopus appendix Girdle dropped - 1609 2 parachutes
LAUNCHING							
Inflation Medium	Ammonia	Helium	Helium	Helium and ammonia Approx. 70 lbs. helium Approx. 30 lbs. ammonia	Helium	Helium and ammonia Approx. 70 lbs. helium and approx. 30 lbs. ammonia.	Helium and ammonia Approx. 70 lbs. helium and approx. 30 lbs. ammonia.
Displaced Air	1170	631		576	649	583	559
Gross Lift	163	539		494 lb.	570	498	476
Gross Load	127 lb.	478	504	434 lb.	522	436	438
Free Lift	66 lb.	61		60 lb.	48	62	38
Percentage Free Lift of Gross Load	15.8%	12.6%		13.8%	9.2%	14.2%	8.7%
Rate of Rise	530 feet per min. 1100 " " " (300 to 200-100 mb 100 mb ceiling)	1020 feet per min.		860 feet per min. 1000 feet per min. 1270 feet per min. to 25 mb	14.2% 12.45 10.65	14.2% 12.45 10.65	700 ft. per min. 950 ft. per min. 1120 ft. per min.
Weather	Overcast 4 knots Definite jet stream >100 knots at 25,000 feet	Clear 10 mph Steady	Clear 20-40 mph - gusty	.5 cumulus Moving from NW at 2500 feet From northwest - 3 to 5 knots (jet stream reported but not observed). Visibility unrestricted	Clear 2-4 knots None	Clear 2-4 knots None	Clear 25 knots None

Other	Definite jet stream >100 knots at 25,000 feet	Steady	20-40 mph - gusty	(jet stream reported but not observed). Visibility unrestricted	None	None	None
Launching Site	U of Minnesota Airport	U of Minnesota Airport	U of Minnesota Airport	U of Minnesota Airport	U of Minnesota Airport	U of Minnesota Airport	U of Minnesota Airport
Time in Contact	1638 Ko. 1100 to 1217	1746 Ko. 132 Mo. 10 min. Both	1746 Ko. 133 Mo. 14 hrs. 58 min. 1342 - July 8 to 0440 - July 9	1746 Ko. 133 Mo. 1 hr. 5 mins.	1746 Ko. 133 Mo. 1 hr. 5 mins.	1746 Ko. 133 Mo. 1 hr. 5 mins.	1746 Ko. 133 Mo. 1 hr. 5 mins.
Miscellaneous			Girdle dropped at 1405				
Airplane type		Beachcraft		None	None	University Club	University Beachcraft
Hours in Contact	1100 to 1217 impact	5-10 min.					
Theodolite Stations on	None	U of Minnesota Airport		U of Minnesota Airport - 1333	U of Minnesota Airport 1045	U of Minnesota Airport 1150	U of Minn. Airport - 1537 - July 23
Hours in Contact		10 min.		7 hrs.	1 hr. 5 mins.	1 hr. 5 mins.	Huron, S. D. - 1520 to 2036- July 24
Truck When Dispatched	1230			1345	1100	1700	
Hours in Contact					To impact	None	
RECOVERY IMPACT							
Estimate Before Flight	None	None	None	Stout Falls, South Dakota	Stout Falls, South Dakota	Denver, Colorado	Denver, Colorado
Actual Impact	Unknown	2 miles west of airport 1 mile south of Circle Pines Vacant pasture	3 miles east and 1 mile south of Fargo, South Dakota at Kyle Schmidt farm.	1.25 miles W of Hugo, Minn.	9 mi. SE of Clear Lake, Wisconsin 1 1/2 mi. SE of Neave, Wisconsin	William Kabes farm, Leigh, Nebraska.	On land of Mrs. C. E. Johnson Route #4, Westington Springs, South Dakota (17 miles SW of Westington Springs).
Load	3 miles east of Cumberland, Wisconsin	Same	Same	Kennebec, South Dakota. Reported in by Jerry Garard.	Same	Same	1905 - July 27
Date and Time	June 25, 1952 1230	June 30, 1952 1925	June 30, 1952 1925	July 9 - approx. 1115	July 15 - 1120	July 21 - 1555 (release)	Approx. 2315 - July 24
Load				July 9 - 1120		Same	Telephone Ballroom - July 28 Gondola - July 27
Notified of Position, How	Magnus 1230	Followed in truck	Followed in truck	Telephone 1215 - Gondola 1315 - Ballroom	Continuous visual contact by recovery crew. 1130 - July 15	Continuous contact by Cub. Magnus phoned position. July 21 - 1620	Project stake-bed truck Hanson, Day
Recovered by	Navy truck Harger, Magnus	Stake truck (all three trucks on scene)	Same	Navy truck - Harger, Day	Navy radio tracking truck Smith, Day	Project stake-bed truck Hanson, Day	July 30 - Maas, Smith
Load	Navy truck Harger, Magnus	Same	Same	Same	Same	Same	July 30 - Maas, Smith
Gear Recovered	Gondola	Complete assemblage	Complete assemblage	Complete assemblage	Complete assemblage	Complete assemblage	Complete assemblage
Miscellaneous	Ballon broke in jet stream. Magnus reported load free-fall. Signal was strong for homing until impact at 1217. Magnus returned and left with truck at 1230. Magnus reported girdle did not drop.	Ballon shattered by inflation gas and gas leaked under canopy. Canopy released and balloon emptied and repaired. Launched with canopy hanging on one side. Top failed to inflate and girdle skinned off top and free fall. Balloon ripped and drifted down to ground. 1746 Mo. still received on ground. 132 received in air only.	Approximately 31 lbs. ammonia sized with helium continuously during inflation.				
C. A. A. CONTACTS							
Pre-flight	0930 - Magnus 1025 - Welinski	1230 - Welinski, Brill 1330 - Howard, Bus 1403 - "	1040 - Welinski, W.R. Bus	1245 - Welinski to Bus	0927 - Welinski to Hanna	1305 - Welinski to Erlwein	1500 - Howard - Robinson
Take off	1105 - Magnus from Beachcraft	1518 - Howard, Bus		1345 - Welinski to Bus	1054 - Welinski to Hanna	1505 - Welinski to Erlwein	1540 - Howard - Robinson
In flight	Magnus			1512 - Welinski to Bus 2140 - Welinski to Hanna 1110 - Welinski to Bus	1112 - Welinski to Hanna		2322 - Winkler to Lerner 0030 - May to Hanna 0500 - Kuth to Hanna 1045 - July 25 - May to ?
Termination	1217 Impact Magnus	1600 - Welinski, Losier	1145 - Howard	1235 - Gondola reported down Welinski to Bus 1335 - Balloon down Welinski to Bus	1145 - Welinski to Hanna	1605 - Welinski to Losier	Not recorded
GONDOLA RECORDS							
Up Camera	9 ft. ran through - exposure O.K.	10 frames before impact		All film ran through exposure O.K.	5 ft. ran through	Exposures for flight (continuing after impact).	Exposures up to altitude
Down Camera	Camera torn from levelling device and motor 9 feet ran through	10 frames before impact		All film ran through exposure O.K.	Exposures for entire flight.	16 frames.	Entire film ran through
Inside Camera	None	None	None	None	Crown - 11 ft. ran through O.K., then view cut off by balloon plastic.	Crown - 50 frames Side - 20 feet exposed O.K.	Side - 20 frames exposed, film folded in accordion fashion.
Baro-thermograph	O.K. but not analyzed	O.K. but not analyzed		Records of complete flight	Not analyzed	Not analyzed	Good record
COURSE CHART							
PRINCIPLE CHARACTERISTICS OF FLIGHT							
Flight	Flight showed increasing rate of rise characteristic of ammonia flights. Broke at top of the jet stream. Load free fall.	Little or no helium went into canopy in 5 min.	1000 lb. test nylon to top of balloon broke and balloon was destroyed in the wind.	Ballon ascended with increasing rate of rise and levelled at theoretical ceiling. At sunset it descended 14,000 feet. Plotted level all night. Glided 5,000 feet the next day and floated level until released by timers.	Diaphragm was not broken. Balloon rose to approx. 9,000 ft. Ballast was dropped until relay in gondola failed. Approx. 2,000 ft. rose of altitude was gained. Load was dropped by radio release to get balloon out of altimeter.	Rope caught in leading ring on top of balloon, remained this way until balloon broke at about 35,000 ft. In the future we must cut this rope short.	Rose to ceiling, floated level to sunset, when it descended at 15,000 ft. Began climbing at 0130 next morning, floated all day, began descending at sunset of second day, and was released by low-altitude blowdown. Balloon floated two more days.
Secret Security Information							

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[illegible]

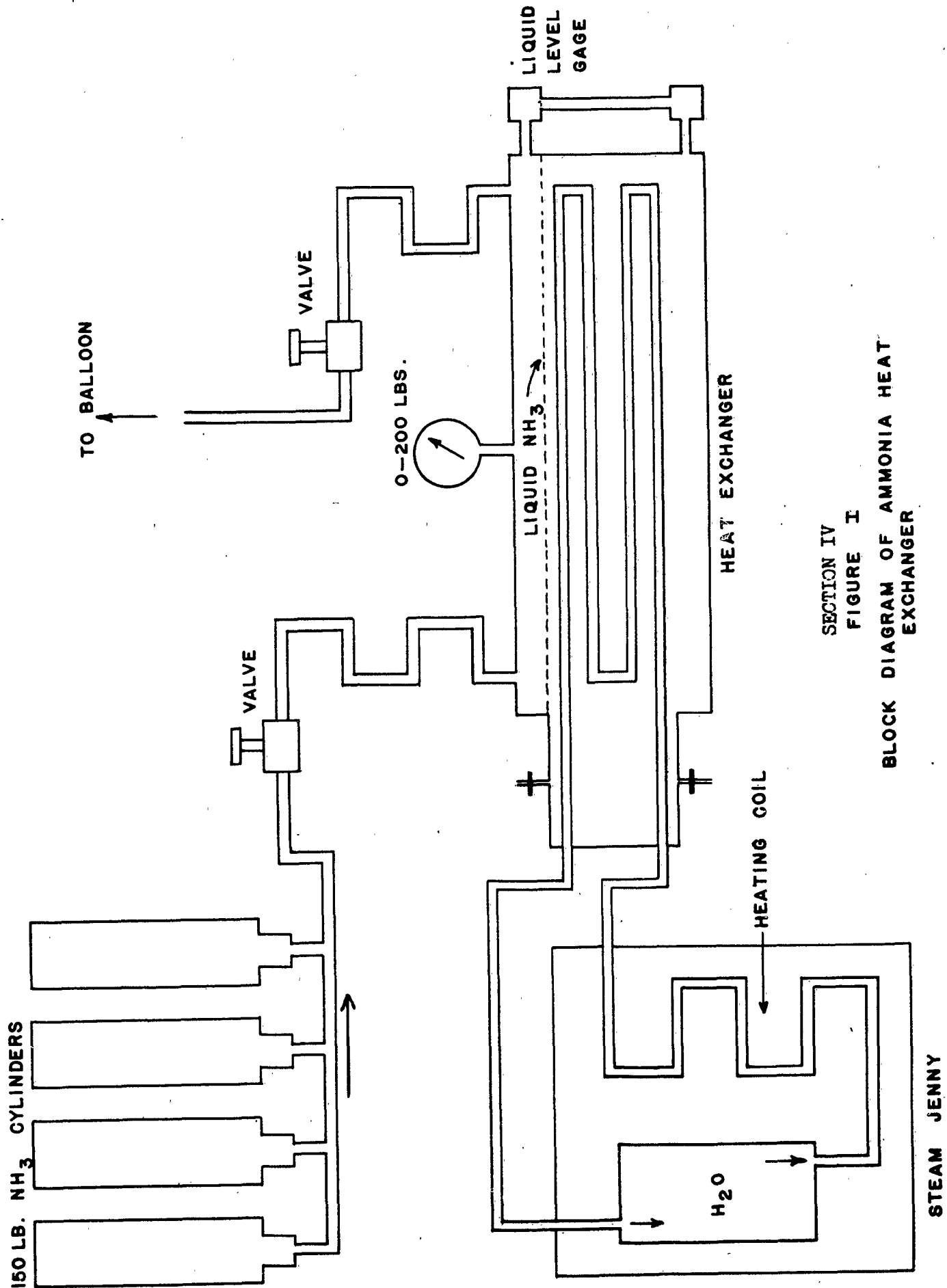
SECRET SECURITY INFORMATION

FLIGHT NUMBER		41		42		43		44		45		46		47		48	
FLIGHT DATA																	
Date Flown	October 2, 1952	October 9, 1952	October 14, 1952	October 16, 1952	October 20, 1952	November 3, 1952	November 4, 1952	November 6, 1952									
Time	1003.38	1251.10	1322.30	1305.46	1310.08	1150.30	1135.40	0802.10									
Balloon Type	Winsen 2-100-V-85 11 Meter Antenna, 10 1/2 valve filament tapes, Standard appendix Rubber under corset, Nylon cloth girdle, Fire tied up	Winsen 2-100-V-93 11 Meter Antenna, Standard appendix (Duct appendix same as Flight #40) Rubber under corset, Nylon cloth girdle	Winsen 2-100-V-92 Duct Appendix Rubber under corset Nylon cloth girdle	Winsen #73-D-0015-185 tapeless Duct Appendix Rubber under corset Nylon cloth girdle	Winsen #73-100-V-169 - 1-mil 1 1/2 filament tapes, Duct appendix Rubber under corset Nylon cloth girdle	Winsen #100-V-126 1-mil 72.8" diameter, Duct appendix in top to 8' above girdle Taped girdle	Winsen #73-100-V-170 1-mil Duct appendix 11' from top to 5' above girdle.	Winsen #73-100-V-171 with of 150-V-117 balloon tape bottom. Wooden thimble on balloon. Duct appendix to above ring.									
Date Packed and Packed	Hansen, Edwards, Smith, Lahti 10-1-52	Smith, Hansen, Edwards 10-3-52	Hansen, Edwards, Rich 10-10-52	Hansen, Edwards, Smith 10-16-52	Hansen, Edwards, Lahti 9-4-52 Hansen, Edwards, Smith 10-18-52	Smith, Hansen, Edwards 6-11-52, 8-26-52 Duct installed 10-27-52	Smith, Hansen, Edwards 9-9-52 Duct installed 10-23-52	Hansen, Edwards, Smith, Rich Hansen, Edwards, Smith, Rich (Inflated at Weaverville, Aug)									
Balloon Weight	232 pounds	232 pounds	232 pounds	1148 pounds	1142 pounds	162 pounds	161 pounds	224 pounds									
Altitude Theoretical Minimum	80,600 76,660	85,500 85,500 (Indicated higher the second day)	86,500 88,300	87,000 26,000	87,000 85,200	86,000 82,900	86,000 86,000	86,300 7,000									
Purpose	Flight constants with command valve and sequence ballast drop.	Duct appendix test with ballast drop. Sunset effect.	Duct Appendix test. Ammonia needed through sunset.	Duct appendix test. Sunset effect on 1.5-mil tapeless balloon	Duct appendix test with 1-mil. Sunset effect on 1-mil balloon.	Sunset and ballast effects on 1-mil balloon with duct appendix.	Sunset and ballast effects on 1-mil balloon with duct appendix.	Ballonet test with duct ap									
Duration Planned	24 Hours	48 Hours	24 Hours	48 Hours	40 Hours	48 Hours	48 Hours	48 Hours									
Actual Duration	1 Hour 40 Minutes	31 Hours 40 Minutes	6 Hours 29 Minutes	40 Minutes	3 Hours 15 Minutes	7 Hours 5 Minutes	6 Hours 35 Minutes	22 Minutes									
How Released	Command Blow Down	Low Altitude Release	Low Altitude Release	Aneroid Blowdown (balloon broke)	Low Altitude Release	Aneroid Blowdown	Aneroid Blowdown	Low Altitude Hatchet Rele									
CONDOLA DATA																	
Condola No.	19	8	4	13	13	15	19	16									
Radio Gear	Transmitter #102 (1638KC) Receiver 9-N Receiver control 8-J. Olland Cycle #13 Antenna Drop #23	Transmitter #103 (1746KC) Olland Cycle #16 Antenna drop #20	Transmitter #103 (1638KC) Olland Cycle #19 Antenna Drop #24	Transmitter #104 (1638KC) Olland Cycle #16 Antenna drop #20	Transmitter #103 (1638KC) Olland Cycle #19 Antenna Drop #20	Transmitter #115 Olland Cycle #17 Antenna Drop #25	Transmitter #111 (1746KC) Olland Cycle #16 Antenna Drop #25	Transmitter #114 (1746KC) Antenna Drop #22									
Blow Down	Blow Down Box #12 Cocks 42,000 Hold 5.0V Fires 30,500 Fire 4.0V	Blow Down Box #34 Cocks 15,000 Hold 5.0V Fires 20,000 Fire 4.0V	Blow Down Box #42 Cocks 37,000 Hold 5.0V Fires 30,000 Fire 4.0V	Blow Down Box #34 Cocks 39,000 Hold 5.0V Fires 30,000 Fire 4.0V	Blow Down Box #34 Cocks 40,000 Hold 5.0V Fires 30,000 Fire 4.0V Delay 1.11"	Blow Down Box #52 Cocks 55,000 Hold 5.0V Fires 31,500 Fire 4.0V	Blow Down Box #52 Cocks 52,500 Hold 5.0V Fires 30,000 Fire 4.0V	Blow Down Box #54 Cocks 40,000 Hold 5.0V Fires 30,000 Fire 4.0V									
Cameras	Up #1 Down #17	Up #29 Down #21 (modified to record Olland Cycle with beam marker)	Up #19 Down #20	Up #15 Down #31 with Olland Cycle recorder	Up #15 Down #21	Up #29 (with marking pip Down #30) with marking pip Thermister Recorder #1 camera #31	Up #24 Down #32	Up #1 Down #33									
Ballast	Sequence ballast drop 10-20-30-40-50-60-70-80-90-100-110-120-130-140-150-160-170-180-190-200-210-220-230-240-250-260-270-280-290-300-310-320-330-340-350-360-370-380-390-400-410-420-430-440-450-460-470-480-490-500-510-520-530-540-550-560-570-580-590-600-610-620-630-640-650-660-670-680-690-700-710-720-730-740-750-760-770-780-790-800-810-820-830-840-850-860-870-880-890-900-910-920-930-940-950-960-970-980-990-1000-1010-1020-1030-1040-1050-1060-1070-1080-1090-1100-1110-1120-1130-1140-1150-1160-1170-1180-1190-1200-1210-1220-1230-1240-1250-1260-1270-1280-1290-1300-1310-1320-1330-1340-1350-1360-1370-1380-1390-1400-1410-1420-1430-1440-1450-1460-1470-1480-1490-1500-1510-1520-1530-1540-1550-1560-1570-1580-1590-1600-1610-1620-1630-1640-1650-1660-1670-1680-1690-1700-1710-1720-1730-1740-1750-1760-1770-1780-1790-1800-1810-1820-1830-1840-1850-1860-1870-1880-1890-1900-1910-1920-1930-1940-1950-1960-1970-1980-1990-2000-2010-2020-2030-2040-2050-2060-2070-2080-2090-2100-2110-2120-2130-2140-2150-2160-2170-2180-2190-2200-2210-2220-2230-2240-2250-2260-2270-2280-2290-2300-2310-2320-2330-2340-2350-2360-2370-2380-2390-2400-2410-2420-2430-2440-2450-2460-2470-2480-2490-2500-2510-2520-2530-2540-2550-2560-2570-2580-2590-2600-2610-2620-2630-2640-2650-2660-2670-2680-2690-2700-2710-2720-2730-2740-2750-2760-2770-2780-2790-2800-2810-2820-2830-2840-2850-2860-2870-2880-2890-2900-2910-2920-2930-2940-2950-2960-2970-2980-2990-3000-3010-3020-3030-3040-3050-3060-3070-3080-3090-3100-3110-3120-3130-3140-3150-3160-3170-3180-3190-3200-3210-3220-3230-3240-3250-3260-3270-3280-3290-3300-3310-3320-3330-3340-3350-3360-3370-3380-3390-3400-3410-3420-3430-3440-3450-3460-3470-3480-3490-3500-3510-3520-3530-3540-3550-3560-3570-3580-3590-3600-3610-3620-3630-3640-3650-3660-3670-3680-3690-3700-3710-3720-3730-3740-3750-3760-3770-3780-3790-3800-3810-3820-3830-3840-3850-3860-3870-3880-3890-3900-3910-3920-3930-3940-3950-3960-3970-3980-3990-4000-4010-4020-4030-4040-4050-4060-4070-4080-4090-4100-4110-4120-4130-4140-4150-4160-4170-4180-4190-4200-4210-4220-4230-4240-4250-4260-4270-4280-4290-4300-4310-4320-4330-4340-4350-4360-4370-4380-4390-4400-4410-4420-4430-4440-4450-4460-4470-4480-4490-4500-4510-4520-4530-4540-4550-4560-4570-4580-4590-4600-4610-4620-4630-4640-4650-4660-4670-4680-4690-4700-4710-4720-4730-4740-4750-4760-4770-4780-4790-4800-4810-4820-4830-4840-4850-4860-4870-4880-4890-4900-4910-4920-4930-4940-4950-4960-4970-4980-4990-5000-5010-5020-5030-5040-5050-5060-5070-5080-5090-5100-5110-5120-5130-5140-5150-5160-5170-5180-5190-5200-5210-5220-5230-5240-5250-5260-5270-5280-5290-5300-5310-5320-5330-5340-5350-5360-5370-5380-5390-5400-5410-5420-5430-5440-5450-5460-5470-5480-5490-5500-5510-5520-5530-5540-5550-5560-5570-5580-5590-5600-5610-5620-5630-5640-5650-5660-5670-5680-5690-5700-5710-5720-5730-5740-5750-5760-5770-5780-5790-5800-5810-5820-5830-5840-5850-5860-5870-5880-5890-5900-5910-5920-5930-5940-5950-5960-5970-5980-5990-6000-6010-6020-6030-6040-6050-6060-6070-6080-6090-6100-6110-6120-6130-6140-6150-6160-6170-6180-6190-6200-6210-6220-6230-6240-6250-6260-6270-6280-6290-6300-6310-6320-6330-6340-6350-6360-6370-6380-6390-6400-6410-6420-6430-6440-6450-6460-6470-6480-6490-6500-6510-6520-6530-6540-6550-6560-6570-6580-6590-6600-6610-6620-6630-6640-6650-6660-6670-6680-6690-6700-6710-6720-6730-6740-6750-6760-6770-6780-6790-6800-6810-6820-6830-6840-6850-6860-6870-6880-6890-6900-6910-6920-6930-6940-6950-6960-6970-6980-6990-7000-7010-7020-7030-7040-7050-7060-7070-7080-7090-7100-7110-7120-7130-7140-7150-7160-7170-7180-7190-7200-7210-7220-7230-7240-7250-7260-7270-7280-7290-7300-7310-7320-7330-7340-7350-7360-7370-7380-7390-7400-7410-7420-7430-7440-7450-7460-7470-7480-7490-7500-7510-7520-7530-7540-7550-7560-7570-7580-7590-7600-7610-7620-7630-7640-7650-7660-7670-7680-7690-7700-7710-7720-7730-7740-7750-7760-7770-7780-7790-7800-7810-7820-7830-7840-7850-7860-7870-7880-7890-7900-7910-7920-7930-7940-7950-7960-7970-7980-7990-8000-8010-8020-8030-8040-8050-8060-8070-8080-8090-8100-8110-8120-8130-8140-8150-8160-8170-8180-8190-8200-8210-8220-8230-8240-8250-8260-8270-8280-8290-8300-8310-8320-8330-8340-8350-8360-8370-8380-8390-8400-8410-8420-8430-8440-8450-8460-8470-8480-8490-8500-8510-8520-8530-8540-8550-8560-8570-8580-8590-8600-8610-8620-8630-8640-8650-8660-8670-8680-8690-8700-8710-8720-8730-8740-8750-8760-8770-8780-8790-8800-8810-8820-8830-8840-8850-8860-8870-8880-8890-8900-8910-8920-8930-8940-8950-8960-8970-8980-8990-9000-9010-9020-9030-9040-9050-9060-9070-9080-9090-9100-9110-9120-9130-9140-9150-9160-9170-9180-9190-9200-9210-9220-9230-9240-9250-9260-9270-9280-9290-9300-9310-9320-9330-9340-9350-9360-9370-9380-9390-9400-9410-9420-9430-9440-9450-9460-9470-9480-9490-9500-9510-9520-9530-9540-9550-9560-9570-9580-9590-9600-9610-9620-9630-9640-9650-9660-9670-9680-9690-9700-9710-9720-9730-9740-9750-9760-9770-9780-9790-9800-9810-9820-9830-9840-9850-9860-9870-9880-9890-9900-9910-9920-9930-9940-9950-9960-9970-9980-9990-10000-10010-10020-10030-10040-10050-10060-10070-10080-10090-10100-10110-10120-10130-10140-10150-10160-10170-10180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11 Knots NW	4 knots SW	Thin OVC	West 3 mph	South 5 mph	Temperature 45°	Temperature 20° Frost forming	Other
Pierre Municipal Airport SE side of hangar	Pierre Municipal Airport In front of hangar	Pierre Airport Apron in front of hangar	Pierre, South Dakota	Pierre, South Dakota	Pierre, South Dakota	University of Minnesota Airport	Launching Site
TRACKING							
746 KC	746 KC	1746 KC	1746 KC	1746 KC	1638 KC	1746 KC	1638 KC
Alt recovered (app 8 hours)	1 Hour 2 Minutes	Antenna did not drop	45 Minutes	22 Hours 12 Minutes	2 Hours 15 Minutes	None	20 Hours 16 Minutes
Cub - Byrne	None	Pacer - Ice, Hanson, Ruch 3 Hours 15 Minutes	Beechcraft 1 Hour	None	None	None	None
None	None	None	None	None	None	None	None
Pierre Airport	Pierre Airport 1610 - 1750 1 Hour	Pierre 1140 - 1325	Pierre, South Dakota 45 Minutes	None	None	None	None
RECOVERY IMPACT							
None	25 Miles NE Chamberlain, South Dakota	None	None	None	None	None	None
4 Miles SE Delsmont, South Dakota	Not known	Not known	Farm of Chas. O. Baddelay	Clark, South Dakota	Clark, South Dakota	Launching site	Actual Impact Balloon
15 Miles SE of Ft. Pierre, South Dakota	3 Miles West of Gann Valley, South Dakota	8 Miles north of Manongo, North Dakota	7.1 Miles east of launching site	Clark, South Dakota	Clark, South Dakota	Launching site	Load
Not known		1940 - November 22, 1952	0956 - November 24	December 7	December 7	1230 - December 9, 1952	Dates and Time Balloon
November 6 - 0835	Approximately November 20 - 1820	November 22 - 1950	Immediate - 24 November 0900	December 6	December 6	1230 - December 9, 1952	Load
Plane November 6	Telephone November 22 - 1530	Telephone November 23 - Load	Aircraft Observer Immediate - 0844- November 24	Telephone through GMA Rapid City December 8, 1952	Telephone through GMA Rapid City December 8, 1952		Notified of Position, How When
Hanson - Mass Hanson - Byrne	Hanson Byrne	Hanson - Byrne	Magnus-Anderson Magnus-Anderson	Hanson - Anderson Hanson - Anderson	Hanson - Anderson Hanson - Anderson	Launching crew Launching crew	Recovered by Balloon Load
Complete Assemblage	Complete Gondola	Complete Gondola	Complete Assemblage	Complete Damaged Assembly	Complete Assemblage	Complete Assemblage	Clear Recovered
Mention of balloon in report raised bubble height about 20 feet. Plan to walk bubble and load to provide new clearances from GMA. Wenman abandoned because of bad forces on bubble.	Sunset on balloon observed at 1717.	12 pounds of ballast shot recovered in bottom gondola cover.	Good Weigh-off	Complete Damaged Assembly	Complete Assemblage	Gas started to transfer into upper third of balloon pre- sently. After it was erected and the cover removed, this gas and the wind carried the top of the balloon down wind into some telephone poles and lines. The gondola did not leave the launcher's hands.	Platform launched because of large volume of bubble at ground level. Slow inflation (over 1 hour) filled gas length, bubble quite full. Smooth launching. Mixture of Helium and air believed quite homogeneous.
GMA CONTACTS							
0710 - Ruch to Carlson	1540 - Ruch to Carlson	0950 - Ruch - Carlson	0700 - Ruch to Carlson	1840- Ruch to Carlson	1130- Ruch to Watson	1015- Ruch to Carlson	Winman
0730 - Ruch to Carlson	1700 - Ruch to Carlson	Pierre GMA Made own observations	0830 - Ruch to Carlson	1955 - Ruch to Carlson	1220- Ruch to Watson	Howard	Takeoff
0820 - Kurth	None	None					In Flight
Pierre - Mass to Anderson	Pierre - Mass to Anderson November 20 - 1830	After recovery - Ruch to Carlson	0900 - Ruch to Anderson	2252 - Ruch to Carlson	University of Minnesota Airport	1230 - Ruch to Carlson (cancellation)	Termination
GONDOLA RECORDS							
One-half film	10 Feet did not run through (photo of parachute)	Entire film ran through Exposures visible through sundown	7 Frames of balloon in air. These following taken on ground after impact.				Up Camera
Exposures after impact	10 Feet did not run through (Oil and Cycle pipe)	No pictures recorded because of cover on bottom of gondola. Good Oil and Cycle record.	3 Frames				Down Camera
None	None	None	None	None	None	None	Inside Camera
							Other
							Baro-Thermograph
COURSE CHART							
None	None	None	None	None	None	None	None
PRINCIPLE CHARACTERISTICS OF FLIGHT							
Aborted flight due to large leak in top of bal- loon. First release actu- ated by ratchet blowdown.	Climbed at essentially a constant rate of rise of 1000 ft/min through sunset and through the tropopause. Sister of this balloon, without tapes also failed this to poorer quality attributed to this to poorer quality of polyethylene and was skeptical of this balloon. The night condition and fast rate of rise imposed a sev- ere temperature condition.	Superficial contribution by tapes appears to be an important fac- tor. Launching bubble filled to what was considered a safe upper limit of inflation. (This balloon is approximately 12' shorter in gore length than the previous ones) Bottom gondola cover not removed prior to flight preventing normal antenna drop and telemetering.	Flight only in air 45 minutes because of hole in balloon.	Flight with unusually light load was initially over in- flated. Helium was then sucked out of balloon with intake manifold of truck engine. Balloon believed good. Failure possibly due to low light temperatures in climb. No break at tropopause noticed.	Very good sunset and ballast effects obtained for double-taped balloon. Very slow effects obser- ved on balloon in launch through night possibly caused by changes in radiation.	None	Also Winman flight #18 Break observed in rate of climb at tropopause. Air mixture more sensitive to lapse rate than pure helium. Did not reach ceiling before sunset and went all through night in equilibrium on initial free lift. Hit theoretical ceiling after sunrise.

SECTION IV
AMMONIA FLIGHTS

I. Technique of Inflating Balloons with Ammonia. At a very early stage in the Balloon Project the use of ammonia as an alternative lifting gas to helium was considered. As the molecular weight is $3\frac{1}{2}$ times that of helium there is a corresponding loss of altitude for an equivalent sized balloon of 15,000 feet. It was felt that this could be made up very easily by the use of a larger balloon and that this was therefore no real problem. Ammonia is normally supplied as a liquid in cylinders at a pressure of about five or six atmospheres and it is necessary to vaporize the ammonia into the balloon. The ammonia has a very large latent heat of 327 calories per gram which is comparable with the latent heat of evaporation of water so some kind of heat exchanger is necessary to vaporize the necessary inflation gas. A diagrammatic outline of the heat exchanger is shown in Fig 1. A commercially available high pressure steam jenny, traylor model, manufactured by the Homestead Valve Manufacturing Co. Corroopolis, Pa., was obtained. The output of this "Jenny" is stated as being equivalent to that of a 25 hp steam boiler. It uses kerosene burners and supplies circulating hot water or steam. The hot water circulation output of the steam jenny was connected to a heat exchanger as shown which could be fed with the liquid ammonia and the vapor carried off to the balloon. This system was quite simple to set up and operate and the inflation went easily. It was only necessary to control the liquid ammonia valve by watching the liquid level gage and maintaining the heat exchanger pressure at about 100 pounds while the ammonia was evaporating into the balloon. The gas valve in the balloon line was throttled down to keep the ammonia pressure at a value so that the liquid in the heat exchanger did not boil violently as this caused liquid to be blown down the inflation line and to get into the balloon. An inflation using ammonia with this set-up sufficient for a gross



SECTION IV
FIGURE I
BLOCK DIAGRAM OF AMMONIA HEAT
EXCHANGER

lift of 400 pounds could be completed in less than one hour. Precautions were taken to wear gas masks when working around the equipment and the personnel participating in the launching operation wore gas masks, as in the early flights, at least, the bottom of the balloon was open and ammonia vapor could escape occasionally to the surroundings. The inflation of the balloon and the launching proceeded according to the usual method except that the larger volume necessary because of the lower lift of the ammonia required that the inflation volume be utilized to the utmost. Balloons of 73' diameter packed by the Minnesota method had a marginal inflation volume to handle the usual gross loads flown at that time if pure ammonia were used. In one of the flights, accordingly, a larger volume balloon was used and this problem did not exist. Because of its greater molecular weight the transfer time of the ammonia gas from the bottom to the top of the balloon after launching is about four times as long as that required for helium and this was observed during flight. The time required for the gas to completely enter the top portion of the balloon after it left the ground was about eight minutes with the same size diaphragm opening that allows helium transfer in two minutes. It should be noted that the flight characteristics of a balloon inflated with ammonia are different from that of a balloon inflated with helium as the ratio of the specific heats at constant pressure and constant volume is different for ammonia than helium and due to the higher molecular weight the air displaced is much larger for the same gross lift in the case of ammonia.

Another important effect is the large radiation absorption of ammonia in the infra-red region as shown in Table II. It is significant that the largest absorption occurs in a region close to the maximum of the black body radiation of the earth, that is at about 10 microns. Because of the possibility that radiation clamping to the earth would provide a source of stability which would reduce the ballast requirement for long duration flights and also because the leakage rate for ammonia out of the balloon is much lower than helium because

Table I

Absorption and Reflection of Plastic Films

Average Wavelength	UV 4000 Å	Visible 5500 Å	Infra-Red 7000 Å	Room Temp. 500,000 Å
Reflectivity % V-Film Polyethylene	10 6	5 5	5 5	11 4
Absorptivity %/Mil V-Film Polyethylene	4 3	1 1	1 1	30 6

Table II

% Transmission of (NH₃) Ammonia in a 4cm. cell at 760 mm Hg. Pressure

λ (Microns)	% Transmission
6.7	24
8.7	26
20.75	79
22.9	93
27.3	83
29.4	82
32.8	62

Strong, Physical Review, 37, 1565 (1931)

of the higher molecular weight and further because it provides an alternative inflation medium which might be available in remote points where helium would be expensive to provide; a considerable effort was made to experimentally evaluate ammonia as an inflation medium. The flights with ammonia included both pure ammonia and ammonia diluted by helium so that the infra-red absorption was maintained sufficiently but that otherwise the helium flight characteristics are produced.

II. Analysis of Flights using Partial, or Complete Ammonia Inflation. The following summarized series of 11 flights was made to study the effect of ammonia on the stability of the balloon particularly after sunset and were all conducted on 70' diameter polyethylene cells.

Flight #11. A 1-mil thick balloon was inflated with about 50% helium and about 50% ammonia. The ammonia was vaporized by a steam jenny. The balloon rose at a nearly constant rate of 860 feet per minute and slowed down a little near ceiling. The balloon overshot the ceiling calculated for the mixture which was a sign that it was valving out the unmixed ammonia and decreasing the gross load. This balloon was suspected of having a sizable hole and reversed its motion and returned to the ground. The balloon had no appendix so that air could be taken in freely. The result of the experiment in regard to the effect of ammonia is inconclusive.

Flight #15. Flight #15 used a 1-mil balloon inflated with pure ammonia vaporized from the cylinders by means of the steam jenny. In this flight 870 pounds of air were displaced. This is an absolute maximum for the 70' diameter balloon with the Minnesota method of packing. The balloon was launched at 1553. It went into level flight at 1720, somewhat below theoretical ceiling which is consistent with the fact that it had no appendix and that air could be taken in freely. A pre-sunset effect showed up at 1910 and the balloon descended at 332 feet per minute which increased during actual sunset to 456 feet per minute.

At 2046 the balloon began to level upon reaching the 180 mb level. It reached 210 mb as the minimum altitude and then began to climb back and reached 185 mb at 2230 at which time the timers set the load free. We attached great significance to this flight because it was the first case and the only case we know of in which a balloon leveled and climbed after dropping almost to the tropopause. A graph (Figure II) of the upward infra-red flux prepared by Dr. Mantis is attached and shows that it begins to increase at about 30,000 feet. Presumably at higher altitudes the flux remains constant.

Flight #17. Flight #17 was inflated with pure ammonia vaporized by means of the steam jenny and used a 1-mil balloon. Unfortunately on this flight the appendix was fouled by the girdle preventing the balloon from valving so that it burst upon reaching ceiling. This fact was determined by the up-camera carried as a standard part of every flight. The initial velocity upward was 550 feet per minute which increased to 1170 feet per minute just as the balloon reached ceiling. This acceleration is rather more than is observed with helium flights subsequent to this. This was very interesting to us at that time because it had been assumed that balloons had a more or less constant rate of rise. Subsequent flights both with ammonia and helium have shown that this is not necessarily true. The results are inconclusive in regard to the ammonia effect at sunset because of the balloon failure.

Flight #18. Flight #18 was another pure ammonia inflation but the balloon failed before launching due to the sun heating the aluminum girdle, which at that time was uncovered, and destroying tapes and fabric near the girdle because of the high temperature.

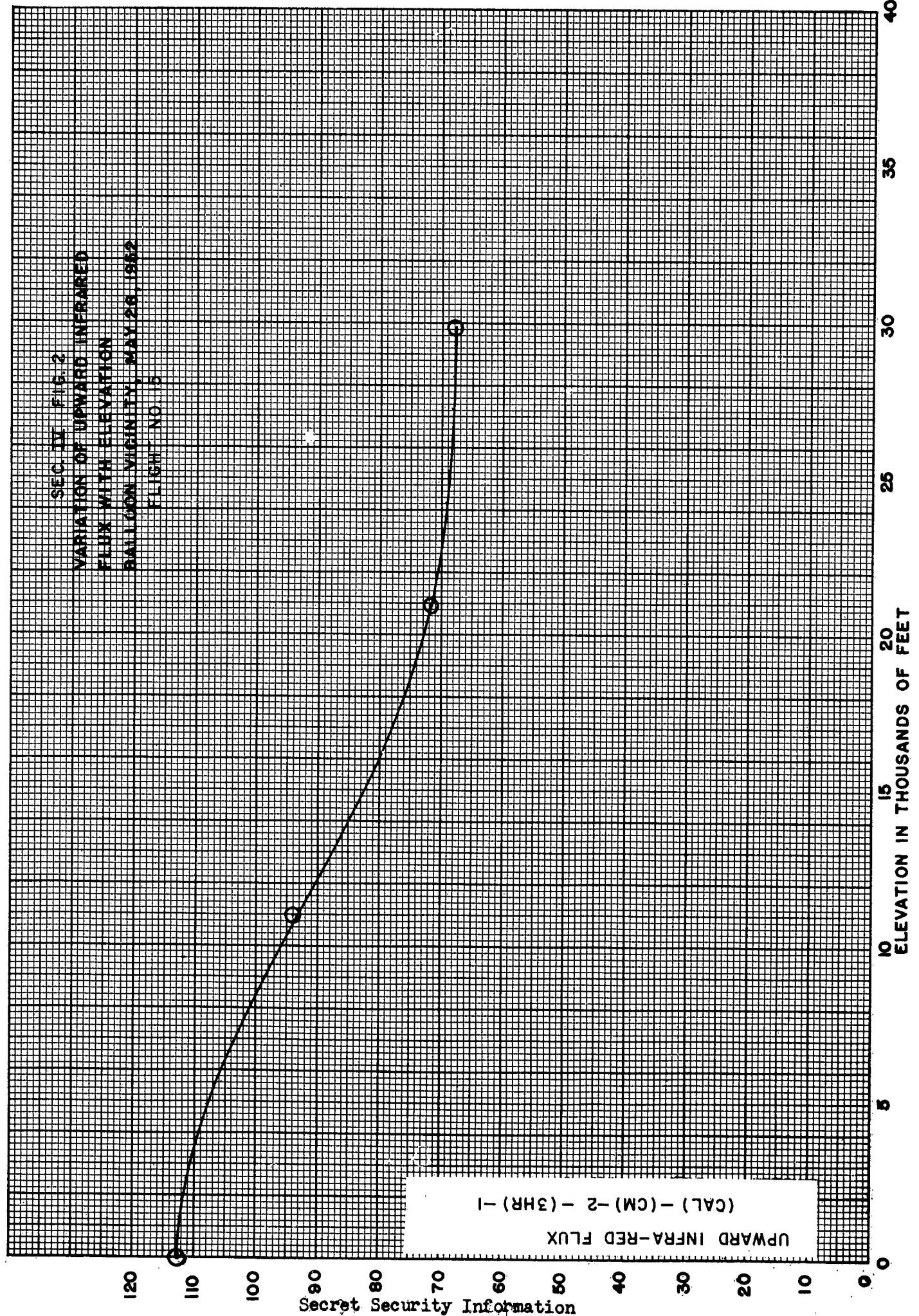
Flight #21. Flight #21 was a 100% ammonia inflation using the steam jenny for vaporizing ammonia and it used an 1161 type balloon which has a volume of $\frac{3}{4}$ of a million cubic feet. The large balloon was used to avoid the marginal inflation with the Minnesota packing method.

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In this flight the canopy of the balloon slid over and the ammonia gas which does not transfer as readily as helium through the opening filled the top very slowly. The top finally erected at 35,000 feet as shown by the up-pictures but the balloon broke upon reaching the high wind region which that day could be classified as a jet stream at about 40 to 50,000 feet. This flight is inconclusive with regard to the ammonia stability.

*Flight #24. Flight #24 used a partial inflation of helium and ammonia with 70 pounds weight of helium gas and 30 pounds weight of ammonia gas. Some investigation had been made of the absorption of ammonia and it was decided that this fraction of ammonia was enough to completely absorb all of the infra-red radiation impinging on the balloon at 60,000 feet. (See Table II). A double-walled balloon was used because the limitation of having pure ammonia on the inflation volume was not present. It had a standard appendix. The ammonia was carburated into the helium by small openings in the manifold and the pressures were measured to determine the relative concentration. The heat content of the ammonia cylinders was used to vaporize the ammonia and as the gas evaporated the cylinders cooled noticeably.

This flight reached ceiling and floated level during the day without any evidence of the "Howell" effect. At sunset it dropped 15,000 feet and leveled again and floated during the night until next morning. At sunrise it climbed 5,000 feet. The lowering of the ceiling altitude the second day from 20 mb to 35 mb showed that the balloon was nearly half full of air. The conclusions are that stability was definitely imparted to this balloon but the certain presence of air as a perturbing factor makes the exact contribution of the ammonia uncertain.

Flight #26. Flight #26 was similar to flight #24 with a carburated mixture of ammonia and helium but due to the fact that the top rope snarled

in the ring and the balloon could not erect the flight was a failure and the balloon broke at 35,000 feet. There are no conclusive results in respect to the ammonia from this flight.

*Flight #27. Flight #27 again used a carburated mixture of 70 pounds of helium and 30 pounds of ammonia but a new improved appendix was used in which the straight skirt was closed off and four side arms made of Mylar quarter mill material were fixed which could hang down and shut off the openings after the balloon had valved. The balloon was a double-walled balloon and on the ascent accelerated from 700 feet per minute to 1400 feet per minute reaching a ceiling of 83,000 feet. It floated level from 1710 to sunset at 1950 then dropped 15,000 feet and leveled. At 0130 the next day it climbed at 26 feet per minute until sunrise and then climbed at 92 feet per minute to 30 mb which is 7 mb below the ceiling of the previous day showing that about 25% of the volume of the balloon at that time was air. It remained essentially level until sunset at 2030 of that day and then returned all the way to the ground. It was significant that near sunset of the second day the balloon went over an over-cast which was absent at the first sunset. Again on this flight we have a case where the balloon has a definite stabilizing influence which may well be the ammonia but again the appendix did not exclude air from the balloon and the perturbing effects of air are present.

Flight #28. Flight #28 was made as a control flight for flights #24 and #27 using the new side arm appendix and a double-walled balloon but with 100% helium inflation. This balloon showed the "Howell" effect which was absent on both of the previous ammonia flights, in which, after reaching ceiling, it began to descend in about one-half hour. The balloon apparently took air despite the presence of the appendix and drifted downward at about 25 feet per minute. At sunset the rate changed to 75 feet per minute. The balloon continued downward until reaching the 300 mb level and released at 0420 the next day. The balloon

probably had a large fraction of air and shows a very small sunset effect. The rise rate was 803 feet per minute and constant. This balloon floated in clear weather towards the end of the first day but was launched with some overcast. The conclusions are that the change in rate caused by sunset was very small and indicated a decrease in the positive lift much less than the 6% now thought to go with this type of balloon. However, the balloon did contain air and it did not become stable in static equilibrium as did flights #24 and #27.

Flight #30. Flight #30 was again made with a carburated mixture of helium and ammonia, 70 pounds of helium and 15 pounds of ammonia with a double-walled balloon equipped with a standard appendix. The balloon, however, apparently had a leak which became evident at ceiling. The ascent rate increased from 647 to 864 feet per minute and the flight curve then bent over and the balloon began to descend just before reaching ceiling. The balloon showed an ascent acceleration but really gives no conclusive information on the ammonia stability effect.

*Flight #43. Flight #43 used a carburated mixture of 70 pounds of helium and 25 pounds of ammonia with a double-walled balloon but was the first ammonia flight made with the new duct appendix which definitely excludes air. It rose at approximately a constant rate of 690 feet per minute, bounced a little bit upon reaching ceiling at 1510. It began a sunset descent at 1700 initially 440 feet per minute but slowed to 295 feet per minute. It reached 300 mb and cut loose the load at 1940. This flight does not differ appreciably from pure helium flights made with the duct appendix. It is significant that the flight was over a complete overcast during the whole flight time which may be associated with the fact that no evidence of stability was noticed.

The general conclusions from this series of flights are that the earth radiation has a definite effect on the balloon but that it is difficult to ascer-

tain the relative effects of the ammonia on stability following sunset because of the presence of air and because of the obvious variations in the magnitude of the radiation. It was decided to prepare instrumentation suitable for measuring the upward infra-red flux and this is now in process and future ammonia flights will include this type of instrumentation.

One factor seemed evident on the NH_3 flights - namely that the increase of velocity on ascent was larger with NH_3 than with helium. Table I compares eight NH_3 or partial NH_3 inflations with eight helium inflations in the same initial velocity range. There seems to be a significantly larger ratio of velocities between low and high altitude with NH_3 than with helium. If the balloon acquires additional lift from radiation superheat as it ascends, then this effect would be expected to be larger for NH_3 filled balloons than pure helium due to the radiation absorbing properties of NH_3 especially for infra-red earth radiation. This point is being investigated experimentally and will be reported at a later date.

Some data are attached which give the per cent transmission of ammonia for infra-red radiation taken from the work of John Strong reported in Physical Review (Table II) and another table giving some data obtained by E.P. Ney and L. Bohl of Minnesota on the reflectivity and absorptivity of polyethylene material and V-film material ("Mylar") for the general wave length regions lying in the infra-red, visible and the ultra-violet (Table I). It is quite clear that polyethylene itself has a sizable absorption in the infra-red and that this effect must be considered as well as the absorption of the ammonia in producing stability.

Table I

Comparison of NH_3 and Helium Flights on Ascent

(1) Flight No.	(2) Initial Rate ft/min 1000-300 mb	(3) Intermediate Rate ft/min 300-100 mb	(4) Final Rate ft/min 100 mb - Ceiling	(5) Ratio $\frac{(1000-300)}{(300-100)}$	(6) Ratio $\frac{(1000-100)}{(100-\text{ceiling})}$
NH_3	11	860	760	1.0	.88
	15	750	1200	1.2	1.6
	17	490	1070	2.0	2.2
	21	530	-	-	-
	24	860	1270	1.5	1.5
	27	700	1420	1.4	2.0
	30	740	865	1.2	1.2
	43 (Duct)	775	833	1.1	1.1
	28	750	880	1.1	1.1
	20	811	1200	1.1	1.5
Helium	16	830	1200	1.2	1.4
	35	825	1000	1.1	1.2
	38	790	1020	1.1	1.3
	40 (Duct)	445	750	1.1	1.7
	41 (Duct)	680	Valved	-	-
	42 (Duct)	430	530	-	-

$$\text{Av } \text{NH}_3 \quad \frac{(1000-300)}{(100-\text{ceiling})} = 1.6$$

$$\text{Av Helium} \quad \frac{(1000-300)}{(100-\text{ceiling})} = 1.3$$

$$\frac{(1000-300)}{(300-100)} = 1.4$$

$$\frac{(1000-300)}{(300-100)} = 1.1$$

SECTION V

BALLASTING EFFICIENCY

The material given here is not intended to be final but instead, representative of the thinking so far on this subject.

Introduction:

If due to sunset or to loss of gas a balloon, initially at ceiling, loses some lift it will descend. The descent can be checked by dropping a weight of ballast equal to the loss of lift or by adding gas to the bag. If the gas was originally stored in some form in the gondola, there will always be space for enough of it in the bag to check the descent if the gas is lighter than air. If the gas has a molecular weight in a scale in which air has molecular weight unity, the weight of gas to be carried is smaller than the weight of equivalent droppable ballast (say sand bags) by the factor $1/\gamma$. For Hydrogen $\gamma = 29/2 = 14.5$; for Helium $\gamma = 29/4 = 7.25$; for Ammonia (NH_3) it is $29/17 = 1.7$. In principle, for example, one need carry only $1/14.5$ the weight of Hydrogen as of sand. However, the gas must be stored in some form in the gondola and one must therefore take into account the weight of container, or if the gas is to be generated by a chemical reaction, the weight of the reactants. We attempt below to get some limits on these weights and thereby to establish the feasibility of a given scheme.

In order for a ballasting system to be better than dropping sand bags it will have to provide more lift for the weight of system carried than one gets from sand bags. We define a figure of merit Q which will have a value of 1 for sand bags and greater than 1 for any system which may be considered a successful competitor to sand bags. Then

$$Q = \frac{\text{Total lift obtainable}}{\text{Total weight of system carried}}$$

We do not include in our system weight, the weight of piping, valves and controls on the assumption first, that by proper design these may be made of negligible weight compared to the rest of the system, and second, that much of this weight is common to all systems. By this process we reduce the problem to a study of the intrinsic worth of a system.

We shall consider the methods outlined below:

1. Gas storage in tanks
 - A) Hydrogen
 - B) Helium
 - C) Other gases
2. Generation of gas
 - A) Lithium Hydride and water
 - B) Lithium Hydride and Ammonia
 - C) Lithium Hydride and Ammonia - water
3. Liquified gases
 - A) Helium
 - B) Hydrogen
 - C) Ammonia
 - D) Others

All considerations will be based on the requirement for sustained flight for many days.

Storage of Gas in Tanks:

The problem here is to get a balloon-borne tank of minimum weight to store a quantity of lift gas. We may relate the strength and weight of a container to the amount of stored gas.

The best shape of container is a sphere. A cylinder with spherical end bells is somewhat worse (4/3 the weight for a long cylinder). Considering only a sphere:

Its mass is $M = 4\pi r^2 t \rho$

with r the radius
 t the wall thickness
 and ρ the wall density

its volume is $V = 4/3 \pi r^3$

the stress in the wall is

where P is the gas pressure.

$$S = \frac{Pr}{t}$$

eliminating r and t among these three relations and considering the yield stress S_y .

$$M = 3/2 PV (P/S_y) = 3/2 NRT (P/S_y)$$

where N is the number of moles of contained gas, and the gas is assumed to obey the gas law.

From this we see that M/N , the mass of container per mole of stored gas is:

- A. Proportional to the absolute temperature T . (Actually to the gas kinetic energy per mole).
- B. Proportional to a material constant P/S_y . This is a measure of the weight to strength ratio.

The quantity P and M/N are tabulated below for some representative materials at various temperatures. The latter correspond to an ordinary outdoor temperature, a typical stratosphere temperature, and the boiling temperature of liquid nitrogen at atmospheric pressure. Once the container is completely pressurized at some temperature it will burst if allowed to get warmer before the gas is at least partially used.

Material	ρ/S_y (Gms/erg)	27°C	M/N (Gms/mole)	
			-55°C	195°C
Aluminum alloy	2.0×10^{-9}	75	55	19
Stainless Steel	3.1×10^{-9}	116	84	30
Magnesium	1.1×10^{-9}	45	33	11.6

Each mole of contained gas displaces one mole of air when it is allowed to flow into the balloon. If A_g and A_a are the molecular weights of lift gas and air respectively, $M+NA_g$ is the system mass and NA_a is the mass of displaced air. The figure of merit of the system is then:

$$Q_1 = \frac{NA_a}{M+NA_g} = \frac{A_a}{(M/N)+A_g}$$

provided that the container is not jettisoned. Even in the latter case one is not justified in assigning a higher figure of merit unless the gas is carried in a multitude of small containers, since one large ballast drop suffices for only one extra day of flight. In this connection note that the container size is not involved in the expression for M/N .

If the containers may be dropped we have:

$$Q_2 = \frac{NA_a + M}{M+NA_g} = \frac{A_a + M/N}{M/N + A_g}$$

$$= Q_1 + \frac{M/N}{M/N + A_g}$$

The table below lists Q_1 and Q_2 for magnesium spheres at 27°C and -195°C storing helium. Hydrogen is very slightly better. Heavier gases are not worth considering.

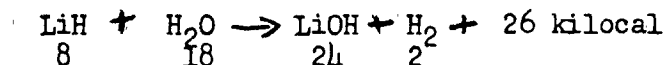
Gas	T°C	M/N	Q_1	Q_2
He	27	45	0.6	1.5
He	-195	12	1.8	2.5

From the table we may deduce that if the container is not to be cooled it must consist of several parts which may be dropped (ie $Q_1 < 1$). Even so the value $Q_2 = 1.5$ (where the container is dropped) represents a case where the material is stressed to a dangerous degree. A small safety factor nullifies the advantage. If the container is cooled to liquid N_2 temperature an apparently good value of Q results, permitting some safety factor. However the weight of the coolant and its container considerably decreases this value.

We conclude that carrying gas aloft in spheres has only borderline practicality. If stronger and lighter alloys may be fabricated into the desired shape, reducing ρ/S_y to say 1/3 the value for Magnesium, the method then may be quite practical.

Generation of Gas in flight:

a) The light weight of Lithium Hydride (LiH) makes this method worth considering. The reaction with water and the molecular weights are:

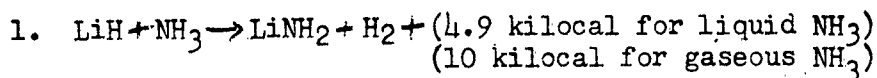


The maximum Q is obtained by neglecting the container weight and assuming that the LiOH may be jettisoned. The 2 grams of H_2 displace 29 g of air giving:

$$Q_{\max} = \frac{29+24}{8+18} = 2.0$$

If the LiOH were not dropped this would reduce to $29/8+18 = 1.1$. Other than the mechanical one there are two difficulties with the simple reaction above. The water is likely to freeze when not in use - and when it is being used the heat of reaction is enough to vaporize about 2.5 moles of water per mole of water used. Possibly the two effects may be used to compensate each other. A suggestion for using the heat of reaction is discussed in (c).

b) There is a reaction of LiH with ammonia



The liquid reaction occurs extremely slowly as determined by trial. The gaseous reaction occurs rapidly only at elevated temperatures ($\sim 450^\circ\text{C}$). Since NH_3 and H_2O have nearly the same molecular weight, the Q for the NH_3 reaction is nearly the same as for H_2O . The low reaction speed is too great a drawback.

c) As we shall point out later, the evaporation of liquid NH_3 at the right time for use as a lift gas has considerable difficulty because of its high latent heat. This suggests using the $\text{LiH} + \text{H}_2$ reaction as a source of heat to vaporize NH_3 from a liquid NH_3 , H_2O mixture. The latter will not freeze at stratosphere temperatures. The Q of pure liquid NH_3 is 1.7, and therefore the Q of the mixture will lie somewhere between 1.7 and 2.0 if the solid end product (LiOH) is dropped. The figure of merit for a mixture of lift processes is given by:

$$Q = \frac{1}{\eta} \sum \eta_i Q_i$$

Where Q_i is the figure of merit of the i th processes considered alone, η_i is the ratio of the weight of the i th substance to the weight of the first, and $\eta = \sum \eta_i$. Suppose we carry $\text{NH}_3 + \text{H}_2\text{O}$ mixture in the ratio of K moles of NH_3 to 1 mole of water and to first approximation neglect the container weight.

$$Q_1 = 2.0, \quad Q_2 = 1.7, \quad \eta_1 = 1$$

$$\eta_2 = \frac{K \times \text{molecular Wt. of NH}_3}{\text{molecular Wt. of LiH} + \text{H}_2\text{O}} = 0.65K.$$

$$\eta = 1 + .65 K$$

We get the table:

K	Q
1	1.88
2	1.82
3	1.80
5	1.77
10	1.73

The heat of vaporization of NH_3 is ~ 5.5 kilocal/mole. The water reaction liberates 26 kilocal/mole, sufficient to boil off ~ 4.5 moles of NH_3 .

As an illustration of the effect of container weight we may take the mixture with $K = 3$. For a container which will not be dropped and has weight 10% of the substances it holds we have as before:

$$\begin{aligned} Q_1 &= 2.0 & Q_2 &= 1.7 & \eta_1 &= 1 & \eta_2 &= .65K \cong 1.95 \\ Q_3 &= 0 & \eta_3 &= \frac{7.7}{26} = 0.3 \\ & & \eta &= 4.3 \end{aligned}$$

and $Q = 1.3$

While if the container is dropped, $Q_3 = 1$ and $Q = 1.55$. In order to test the feasibility of the method, liquid NH_3 , water mixtures in various proportions were placed in dewar flasks and stoichiometric additions of LiH of various grain sizes were made. The reaction was followed by continuous weighing of the reaction vessel. It was found that the reaction went very slowly as long as the NH_3 concentration was appreciable, and speeded up only when most of the NH_3 had evaporated due to normal heat leakage. With room temperature 30% NH_3 solution, the reaction rate was still quite small when coarse-grained LiH was added, but the rate was just satisfactory with the fine (powder) grade. The method is therefore unsatisfactory at present.

It is not necessary for the preceding argument that the water and Ammonia be mixed, just so long as the heat of the water reaction is used to liberate Ammonia. This leaves the freezing problem still with us. It is possible that some solution may be found.

Liquified Gases:

We shall treat this subject only briefly here. A proper discussion, especially of liquid Hydrogen, takes a fairly lengthy treatment.

a. Helium.

Liquid Helium has a latent heat of vaporization of only 20 cal/mole and may not be stored in a vessel which does not carry an excessive amount of liquid nitrogen for cooling. It does not appear to be at all practical.

b. Liquid Hydrogen has a latent heat of 218 cal/mole and may be stored for times of 10 - 20 days in a suitable balloon-borne dewar flask without additional refrigerant. The Hydrogen must be largely in the para state for this to be true. The problem is largely logistical. Liquid para Hydrogen is difficult to make and difficult to ship. However, Δ values ~ 5 appear feasible if a large enough container is carried. For some requirements it is possible that liquid Hydrogen is the only solution.

c. Liquid Ammonia is readily vaporized in sunlight but not after sunset when it is likely to be needed. In order to vaporize it at night one may store solar heat in the liquid during the day (it has a high specific heat) and allow the liquid to evaporate and cool at night. The objection, briefly, is that the container must then be strong enough to stand the vapor pressure of the warm Ammonia, and this brings in the same difficulties that appeared in storage of gases.

SECTION VI
SUNSET EFFECTS

A. General Considerations. A large number of flights, mostly with polyethylene balloons have shown that the most stringent limitation on extended flights is the magnitude of the sunset effect on the balloon. During the day the balloon has a certain superheat which would be reduced for the same balloon floating at equilibrium at night. The magnitude of the sunset effect has been shown to be considerably greater than the normal leakage encountered with a good balloon. On occasion, of course, balloons show much larger leakage than sunset effect but it has been demonstrated that leakage can be made small enough so that the sunset effect is the major effect that calls for the expenditure of ballast. For military applications the attempt to carry heavy loads for a long duration becomes more and more difficult because of the sunset effect. The design tendency is to increase the load hanging on the balloon in order to obtain the prescribed duration of the flight. This load would then be mainly used for expending ballast at sunset in order to keep the balloon floating at high altitude for the desired length of time. However, as soon as the gross load of the system is greatly raised the design tendency is then to thicken the material of which the balloon is constructed thereby increasing the magnitude of the sunset effect and calling in turn for a larger gross load mostly consisting of ballast. It can be seen that it is greatly desirable to reduce the sunset effect as much as possible and avoid the chain reaction described above. A number of measurements of the sunset rate of descent have been made on the balloon project and a few measurements have been made of the actual quantity of ballast required to keep the balloon floating level at ceiling. To take a specific example a double-taped 2-mil balloon has a sunset effect of approximately 8.5% of the air displaced per day. This means that with such a balloon, in order to keep it floating level throughout the night it is necessary to expend an amount of ballast equal to 8.5% of the air displaced. Constant percentage of the gross

load displaced implies that the weight of the balloon system will change exponentially with time and if the sunset effect were 8.5% per day this would imply a time constant for the system of 11.7 days. The time constant would be the time it takes a system to get rid of $2/e$ or approximately $2/3$ of its total weight. Since a balloon system becomes more and more difficult to use the heavier it becomes, it is probable that in military applications it would not be desirable to reduce the weight by as much as $2/3$. Therefore the 8.5% per day value would imply a shorter flight time than 11 - 12 days. It is probable that the leakage of a balloon is in the vicinity of 1% per day implying a time constant of the order of 100 days. If it were possible to reduce the sunset effect to the vicinity of 2% to 3% per day the resulting 30 day time constant would be more than adequate for most military applications. For this reason one of the objectives of the University of Minnesota Balloon Project has been to investigate all possibilities for reducing the sunset effect. This can be done by using material which absorbs less solar energy or by using a smaller amount of material in the balloon. The data so far obtained seemed to indicate that the balloon materials which are used absorb approximately 20 watts of solar power per pound of balloon material with a slight indication that tapes may absorb relatively more per pound than polyethylene. Since polyethylene is not fundamentally a strong material, having a breaking tensile strength of only 2000 pounds per square inch, an obvious method of attacking the sunset problem is by going to plastics with the same absorption but with greater strength thereby allowing the balloon to be made considerably lighter and thereby less absorptive. The program that has been carried out in this respect is to fly balloons made of Mylar, a transparent plastic with a tensile strength of approximately 26,000 pounds per square inch at the breaking point. Measurement of the sunset effect has been obtained on

one such balloon and it appears to be approximately 3.3% which would be a very acceptable value.

When the balloon does not intake air the sunset rate of descent can be quite well related to the weight of the balloon itself and the weight of air displaced. Equation (4) of this section is reproduced here to show the relationship between sunset rate of descent and the other quantities.

$$v = 818 \frac{B}{A} \quad (4)$$

where v is the sunset rate in feet/minute

B is the balloon weight

A is the weight of air displaced

It can be seen from this equation that in order to reduce the sunset rate and with it the magnitude of the sunset effect it is necessary to make the balloon as light as possible in comparison with the air displaced by the flight. In order to use the equation to estimate a sunset rate of descent one simply multiplies the ratio of the balloon weight to the air displaced by 818 in order to get the rate of descent in feet per minute. It is evident that for a given balloon, the greater the gross load on the system, the slower will be the rate of descent. It is to be expected that the equation will not apply as well for very small balloons as large ones since in its derivation the assumption is made that the thermodynamic drag of the balloon is entirely responsible for its behavior and that aerodynamic drag is negligible by comparison.

B. Rate of Descent of Transparent Balloons at Sunset. The significance of the condition that the balloon be transparent is merely that the rate of energy absorption from sunlight be proportional to the mass, B , of the balloon material. The power absorbed is then μB , where μ is rate of energy absorption per unit weight.

If the only physical change at sunset is to stop the source of power μB , the steady state of flight will require that the same power be supplied by the work done on the balloon in descent. This presupposes that the convection is the same at night as in day, that the cooling of the ground has not affected the flight and that the atmosphere is isothermal.

Let:

A = mass of air displaced

a = molecular weight of air (gm)

R = gas constant per mole

ρ = density of air at height x

p = pressure " " " " "

V and T , volume and temperature of displaced air.

Then the power supplied by the velocity of descent v is:

$$\begin{aligned} P &= p \frac{dV}{dt} = p \frac{dV}{dx} v \\ &= A v p \frac{d}{dx} \left(\frac{1}{p} \right) \end{aligned} \quad (1)$$

Writing:

$$p = \frac{R}{a} \rho T \quad (2)$$

$$\text{and} \quad p = p_0 e^{-\frac{ag}{RT} x} \quad (3)$$

(g is acceleration of gravity) we obtain from equation (1) and its equality to μB :

$$P = gAv = \mu B \quad (4)$$

The procedure is then to determine the ratio μ/g (presumed to be constant) from observations on A , B and v . In some cases v represents a difference of velocities before and after sunset.

Application of equation (4) is made in Table I for eight flights on the Balloon Project and two in Texas on cosmic ray flights ($A = 1.17$ for helium).

Table I

Flight No.	G Gross load Pound	A Pounds	B Pounds	v ft/min	μ/g	$\Delta v\%$
40	422	494	232	348	741	-9
42	421	493	232	417	886	+8
43	375	439	232	442	836	+2
46	408	477	162	269	792	-3
47	334	391	161	250	607	-26
50	504	590	329	494	886	+8
53	470	550	293	443	832	+2
55($\frac{1}{2}$ air)	315	1030	244	227	958	+17
C	495	579	241	292	702	-14
K	438	512	239	440	<u>943</u>	<u>+15</u>
				Ave	818	91612 .179

$$\sigma = 13.5$$

It appears that relation equation (4) holds on the basis of these data within a probable error of 9%. This amount of variation may easily be caused by differences in lapse rates in the stratosphere from day to day.

In absolute magnitude $\mu \cong 4 \times 10^5 \text{ cm}^2/\text{sec}^3$ or

$$\begin{aligned} \mu &= 4 \times 10^5 \text{ ergs/gm sec} = .04 \text{ watt/gm} \\ &= 18 \text{ watts/lb.} \end{aligned}$$

Application of the simple sunset formula has been made at altitudes where the lapse rate in the atmosphere is not measured but is known to be small. If the temperature of the atmosphere is known to increase λ degrees per foot of altitude, descent at velocity v liberates power proportionally to the specific heat at constant pressure, characteristic of the filling gas. In first approximation for helium this is:

$$P' = \frac{5}{2} \frac{R \lambda A}{a} v \quad (5)$$

and equation (4) should read:

$$\frac{\mu}{g} B = A v \left(1 + \frac{5}{2} \frac{R \lambda}{a g} \right) (He) \quad (6)$$

$$R = 8.3167 \times 10^7 \text{ erg/deg}$$

$$g = 980 \text{ cm/sec}^2$$

$$a = 28.8 \text{ gm}$$

$$\frac{5R}{2ag} = \frac{41.58 \times 10^7}{56,450} = 7366 \frac{\text{cm}}{\text{°C}} = 242 \frac{\text{ft}}{\text{°C}} \quad (7)$$

$$\frac{\mu}{g} B = A v (1 + .242 L) (He)$$

where L is the lapse rate in degrees per 1000 feet. It seems evident that the constancy of μ/g in Table I depends upon L being at least remarkably constant and hence preferably small at ceiling altitudes.

C. Ballast Required to Maintain Level Flight at Sunset. Because we have more data which is susceptible to analysis in terms of sunset rates as a function of balloon and load weight we can try to interpret the results of the previous section in terms of per cent loss of lift at sunset instead of sunset rate. In order to do this one must assume the correctness of the convection theory which relates the power that flows into the balloon to the temperature difference existing at a given rate. The following equations are used to derive a relationship between the per cent loss of lift at sunset, the weight of the balloon and the quantity of air displaced.

$$V = 818 \frac{B}{A} \quad (4)$$

$$\text{Power} = gAv = c_1 A^{2/3} (\Delta T)^{4/3} \quad (5)$$

Equation (5) follows dimensionally from convection theory. Solving equation (5):

$$V = \frac{C_2}{A^{1/3}} (\Delta T)^{4/3} = 818 \frac{B}{A} \quad (6a)$$

Because $\Delta T = \frac{F}{A}$ where F is the sunset loss of lift and the other symbols have been previously defined.

$$\frac{B}{A^{2/3}} = C_2 \frac{F^{4/3}}{A^{4/3}} \quad (6b)$$

Finally letting P be the per cent loss of lift at sunset:

$$P = \frac{F}{A} = c_3 \left(\frac{B}{A}\right)^{3/4} A^{1/4}$$

The constant c_3 can be determined from flight #53 where:

$$P = 8.5 ; \frac{B}{A} = .533 ; A^{1/4} = 4.85 ; \left(\frac{B}{A}\right)^{3/4} = .625$$

$$c_3 = \frac{8.5}{.625 \cdot 4.85} = 2.8$$

$$\text{So: } P = 2.8 \left(\frac{B}{A}\right)^{3/4} A^{1/4}$$

The equation can be checked on flight #42 where P was measured as 6.0%.

Solution of the equation gives 7.5% in fair agreement.

The assumptions here are the same as in the previous section with the additional assumption of the gross load dependence predicted by convection theory. The constant inequation can be evaluated from our flight #53. The result of this evaluation is the equation:

$$P = 2.8 \left(\frac{B}{A} \right)^{3/4} A^{1/4}$$

where P is the per cent loss of lift at sunset
 B is the balloon weight in pounds
and A is the air displaced in pounds.

Until more sunset rates are available this equation is the best approximation for the calculation of the per cent ballast drop required in order to keep a balloon of weight B displacing a total weight of air A flying level at sunset. Rates and ballast requirements at sunset may be inferred for several other flights besides flight #50 and these results are summarized in Tables I and II. Table I is the sunset rate of descent for various geometric configurations of balloons with different thicknesses of polyethylene and different quantities of tape. Table II gives the corresponding ballast drops required for the same configurations. It can be seen from these tables that the tapes have an appreciable effect as far as the sunset rates and ballast drops are concerned and it is one of the objectives of our project to eliminate the tapes from the balloon design. If the material from which the balloon is made is strong enough the tapes are actually only a detriment since they can pull out in places and stick to the balloon during its ascent and thereby cause failure. In at least one instance we demonstrated clearly that sticky tapes can cause balloon failure. In this particular flight, which was a double-walled balloon, our up-camera pictures demonstrated that a tape had stuck across and pulled off a large section of polyethylene from the outer layer of the balloon. Had this been a single wall balloon the flight would have been a failure but because of the double wall construction the sticky tape did not cause failure of the balloon. Even with polyethylene balloons, if one makes use of the cylinder type construction

Table I. Approximate Sunset Rate of Descent for Various Configurations of 73 foot diameter cells Displacing Approximately 500 Pounds of Air.

Configuration	Sunset rate of descent
1-mil polyethylene with 1 set of tapes	250 ft/min
2-mil polyethylene with 1 set of tapes	390 ft/min
2-mil polyethylene with 2 sets of tapes	500 ft/min

Table II. Approximate Sunset Percentage Loss of Lift for 73 foot diameter cell.

Configuration	Percent loss of lift at sunset of air displaced
1-mil polyethylene with 1 set of tapes	4%
2-mil polyethylene with 1 set of tapes	6%
2-mil polyethylene with 2 sets of tapes	8.5%

explained elsewhere in this report, it is possible to carry the load by the plastic itself without resorting to the use of tapes.

BALLOON MEETING PROGRAM
UNIVERSITY OF MINNESOTA
December 11 and 12, 1952

Physics - Room 170

Thursday - - - - 0800 - - -REGISTRATION OF GUESTS

0830 - - -Introduction - - - - - Buaas, Ney, Buchta

0845 - - -U/M Launch Technique - - - - - -Winckler

0935 - - -Performance of a Conventional
Skyhook Balloon - - - - - -Ney

1030 - - -BREAK (10 min)

Balloon Aerodynamics & Thermodynamics

1040 - - -(a) Theoretical Calculations - - - - - -Bohl

1145 - - -(b) Experimental Determinations
of Flight Constants - - - - - -Ney

1230 - - -LUNCH

Balloon Shapes & Stresses

1345 - - -(a) Theoretical Considerations - - - - - -Upson

1415 - - -(b) Reac Calculations - - - - - -Bohl

1450 - - -(c) Weeksville Tests - - - - - -Winckler

1535 - - -(d) Duct Appendix - - - - - -Huch

1605 - - -BREAK (10 min)

Principles of Extended Flight

1615 - - -(a) Ballasting Systems - - - - - -Perlow

1705 - - -(b) Special Inflations - - - - - -Winckler

Friday - - - - - 0830 - - -Results of Project GOPHER - - - - - -Moore

0900 - - -U/M Analysis of GOPHER Results - - - - - -Ney

0935 - - -Meteorological Aspects - - - - - -Mantis

1035 - - -BREAK (10 min)

1045 - - -Flight Instrumentation - - - - - -Gilman

1150 - - -Telemetering - - - - - -Howard

1230 - - -Closing Speech - - - - - -Buaas



University of Minnesota Ballroom Meeting - December 11 and 12, 1952. 1100 December 11.

BALLOON MEETING ATTENDANCE
UNIVERSITY OF MINNESOTA
December 11 and 12, 1952

Capt. F.A. Berry	Project AROWA	Norfolk, Va.
Cdr. D.R. Levy	OPNAV	Washington D.C.
Cdr. M.W. Euaas	ONR	Washington D.C.
LCol G.A. Guy	Hq. ARDC	Baltimore, Md.
LCol. N.D. Vaughn	Hqs. ARCS	Nashington D.C.
LCdr. I.J. Scott	BuAer (MA-5)	Washington D.C.
Maj. J.T. Slusher	USAF	Washington D.C.
Maj. G.A. Eckels, Jr.	HQ USAF	Washington D.C.
Maj. T.O. Haig	AFCRC	Cambridge, Mass.
Maj. M.C. Chase	WADC	Dayton, Ohio
Maj. M.J. Govednik	WADC	Dayton, Ohio
Maj. R.J. Nash	AFOAT-1	Washington D.C.
Lt. M.D. Ross	ONR	Minneapolis, Minn.
Lt. H.P. Nielsen	W-PAFB	Ohio
Lt. E.J. DiNoia	RADC	Griffiss AFB
Chief E.F. Lewis	ONR	Minneapolis, Minn.
Harger, AG1	ONR	Minneapolis, Minn.
Dr. Van Straten	USN	Washington D.C.
Dr. H. Thompson Straw	AFOIN Hq USAF	Washington D.C.
Dr. A.H. Howell	Elec Eng Dept	Tufts College
Dr. E.P. Ney	U/M	Minneapolis, Minn.
Dr. J.R. Winckler	U/M	Minneapolis, Minn.
Dr. Homer Mantis	U/M	Minneapolis, Minn.
Dr. Gil Perlow	U/M	Minneapolis, Minn.
Mr. C.A. Main	ONR	Washington D.C.
Mr. E.J. Fister	SCRL	Belmar, N.J.
Mr. H.J. Mastenbrook	NRL	Washington D.C.
Mrs. F.L. Whedon	OC Sig O	Washington D.C.
Mr. R.H. Frost	Stanley Aviation	Buffalo, N.Y.
Mr. R.M. Stanley	Stanley Aviation	Buffalo, N.Y.
Mr. Frank Jewett	GMI	Minneapolis, Minn.
Mr. D.F. Melton	GMI	Minneapolis, Minn.
Mr. J.R. Smith	GMI	Minneapolis, Minn.
Mr. R.I. Hakomaki	GMI	Minneapolis, Minn.
Mr. C.E. Moore	GMI	Minneapolis, Minn.
Mr. O.C. Winzen	Winzen Research	So. St. Paul, Minn.
Mr. Vern Baumgartner	Winzen Research	So. St. Paul, Minn.
Mr. R.H. Upson	U/M	Minneapolis, Minn.
Mr. Leland Pohl	U/M	Minneapolis, Minn.
Mr. Logan Gilman	U/M	Minneapolis, Minn.
Mr. R.R. Howard	U/M	Minneapolis, Minn.
Mr. William Huch	U/M	Minneapolis, Minn.
Mr. R. Thorness	U/M	Minneapolis, Minn.
Mr. Ray Maas	U/M	Minneapolis, Minn.
Miss Marlene Bowman	U/M	Minneapolis, Minn.
Mr. W. Little	OC/Psy War, Army	Washington D.C.
Mr. I.M. Fine	U/M	Minneapolis, Minn.
Mr. Anderson	U/M	Minneapolis, Minn.

BALLOON MEETING

University of Minnesota
December 11 and 12, 1952

IntroductionDr. Charles Critchfield, Project Director

INTRODUCTION

The high altitude balloon group at the University thought it appropriate to begin the presentation and discussion by reviewing the objectives of the project and by taking a general view of the progress that has been made in achieving those objectives. I shall try to do this in a few words and leave details and ramifications to the technical talks that follow.

The general purpose of the project is to understand the factors affecting the flight of a loaded, high altitude plastic balloon and thus produce basic information that will permit developments to meet specific military requirements. It is hoped to culminate results from this project at the end of next year with a compendium of data which can be arranged in handbook form so that specific balloon delivery problems can be met with vehicles which are in agreement with theory and/or flight experience. The method of the project is, therefore, scientific in that it involves discovery of the relevant factors, isolating and measuring them and finally relating them to physical theory. It is inevitable that this pursuit should lead to developments of a rather practical kind but, in the thinking at the University, such developments are incidental to the main objective.

Some of the factors affecting balloon flight are not completely understood and are therefore of true scientific interest. Chief among these is the theory of high altitude winds. The project is occupied to a modest extent in this field

but it is understood that a comprehensive study of the subject is beyond its scope and no flights have been made specifically for such a study.

The second factor of interest to research is the flow of radiation of various wavelengths in the atmosphere. Variation of radiation with altitude, time and effective terrain may be said to be the most important influence on sustained balloon flight. In the course of the past year preparation for the study of the influence of various radiations has been made through developments for measuring gas temperature, for excluding air intake and for modifying the absorption of the fabric and through preliminary analysis of flights containing ammonia, flights taking air, effect of cloud cover, and so forth.

In addition to a knowledge of the heating of the cell by radiation it is necessary to know and understand the relationship between the velocity of ascent or descent and change in buoyancy. This part of the work is known as determination of flight constants. Preparation for measurement of flight constants has occupied the major effort of the group in the last year and has led to many necessary developments including the launching method that you know about, appendix design, a unified gondola containing many adaptations and inventions of sensing elements, automatic releases, cameras and the like and a reliable radio communication and command system. The work has been supplemented by theoretical analysis of diffusion of gases, aerodynamics and convection.

An understanding of the flight constants will permit the group to translate its results into specifications for optimum flight performance. Theoretical work and computation has been done along three major lines to put such specifications on a firm basis. First, balloon flights have been simulated on an electronic computer using such information as was available at the beginning of the project. Those results show that that information is inad-

equate and give some clue as to where the omissions and corrections lie. Secondly, considerations of various ballasting schemes indicate that liquid hydrogen, and perhaps other sources of gas are usable and would provide a significant saving in total load. Owing to the rapid development in the liquefaction of large quantities of hydrogen elsewhere the cryogenic work has not been activated here as originally planned. Thirdly, the theory of stresses in and of the natural shape of the balloon, which was initiated at General Mills has been amplified and applied in a variety of cases. This work has been supplemented by very valuable hangar tests at the Naval Air Station at Weeksville, North Carolina. Here for the first time the large balloons were inspected at full inflation and the deformation under load measured. It was shown, for example, that the loading stress is quickly transferred from tapes to fabric and that there is considerable strain near the top tending to produce the natural shape. Measurement for permanent set after recovery also aids in this study.

The efforts just reviewed occupy the project at the full rate of estimated expenditure. They have entailed a large amount of development and establishing of procedures in the shops and in the field that cannot be listed here. Of particular interest, however, may be the fact that the project is now launching from Pierre, South Dakota, so as to be able to track long flights in the winter westerlies without having the trajectories pass over the Great Lakes. This is facilitated by our mobile tracking and telemetering van which is now at Pierre.

Fifty large balloon flights have been made so far and complete records kept on each whether successful or not. The records and a selection of representative pictures together with an evaluation of the experiment appear in the technical report of the project.

FUTURE PLANS

If the current emphasis in the work of the project meets with the approval of the steering group, the plans for the future are quite straightforward. It is presumed, of course, that Steering Committee policy will not be formulated at this meeting; will require further discussion among the services based on the progress of this project to date and the presentations made today and tomorrow. It should also be pointed out that certain areas included in the original proposal have not been investigated. These include gas generation, power supply, countermeasures and materials research. The first three are relatively inactive by direction and the fourth has not presented us with any problem owing to prior work in that area elsewhere.

The principal effort of the coming year will be the measurement of flight constants, that is, the interrelations among buoyancy, vertical velocity and temperature differences under conditions of varying altitude, season, absorptivity of gas and fabric, and balloon design (ducted, hooded, etc.). These measurements will be integrated to a theory containing as few empirical elements as possible. The theory will then be applied to computer flights for check and for extrapolation beyond the experimental conditions.

Among items of particular interest in studying vertical flight we should mention the absorption of sunlight and earth radiation by tapes, the absorption of infrared at various altitudes and over different covers by ammonia-helium mixtures and the use of air intake for buoying and insulating a descending cell.

Laboratory experiments are to be continued on systems for releasing gas into the balloon during flight. Several flights demonstrating the feasibility of such systems are envisioned. Those using liquid hydrogen should probably be made from Colorado.

It is conceivable that there are balloon systems for which the absorption characteristics and flight constants permit sustained flight without dropping ballast. Indications of such a 'solar engine' appear in the recent flights of record duration by the Gopher project. Our present knowledge is insufficient to account for the low ballast consumption on those flights and it may become necessary to repeat flights having large displacement of air under several conditions of terrain and season.

The inevitable changes in balloon design incurred in this program will be interpreted in relation to the theory and should be tested under full inflation for proof and comparison with the previous tests at the Weeksville Naval Air Station.

Armed Services Technical Information Agency

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